COMMITTEE ON TRAUMA

COURSE MANUAL | 11th Edition

Advanced Trauma Life Support® (ATLS®)

Standardized Trauma Care When Seconds Count

ACS ATLS

Advanced Trauma Life Support
American College of Surgeons

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Eleventh Edition

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Dedication

We dedicate this 11th Edition of the Advanced Trauma Life Support (ATLS®) Course to James K. Styner, MD, FACS, who passed away on January 22, 2024, at his home in Manila, Philippines, at the age of 89 years. Dr. Styner, the developer (along with Paul E. Collicott, MD, FACS) and pioneer of the ATLS Course, was born on July 22, 1934, in Los Angeles, California, and attended the University of California–Irvine Medical School, going on to train in orthopaedic surgery. On February 17, 1976, the tragedy which led directly to the development of the ATLS® Course occurred; Dr. Styner, his wife Charlene, and their four children were returning home to Lincoln, Nebraska, in a plane piloted by Dr. Styner that crashed in a field in rural Nebraska. Following the crash, Dr. Styner struggled to obtain appropriate early injury assessment and care for his family in the rural area. He discussed with Dr. Ronald Craig, a family physician and friend, his concerns about the lack of initial, organized trauma care that he and his children received, to which Dr. Craig famously replied, “You have to train them before you can blame them.” With that, the concept for a course that would teach the basics of trauma care was born.

After initial development, the course was subsequently brought into the American College of Surgeons (ACS) as an educational program in 1980 and was quickly promulgated throughout North America utilizing the regional structure of the Committee on Trauma (COT). ATLS has now been expanded worldwide, having been translated into more than 10 different languages and currently being taught to more than 50,000 learners each year in nearly 100 different countries. This 11th Edition of the Advanced Trauma Life Support Course pays tribute to the early focus on the simultaneous identification and treatment of injuries, while advancing the assessment and skills training provided through multiple resources and modalities for the ATLS learner. Our thanks to Dr. Styner for showing the world how to better approach care of the injured patient.

In memory of Dr. Styner and his dedication to trauma education worldwide, the ACS Foundation is accepting donations to the Trauma Education Fund to help defray the per learner cost of ATLS and other trauma programs in low-resourced areas, and the further development or translations of educational components for trauma education courses. Please visit www.facs.org/trauma-education-fund to make a donation.

James K. Styner, MD, FAC

FOREWORDS

PATRICIA L. TURNER, MD, MBA, FACS

Our commitment to ensuring better outcomes for the injured patient is universal, but practice settings, available resources, languages, and mechanisms of injury are not. The combined efforts of committed leaders from around the world have been successful in advancing the quality of the Advanced Trauma Life Support® (ATLS®) Course by ensuring that course content is relevant in all countries and systems that possess any degree of infrastructure to support trauma care. The ATLS Course was designed to provide physicians and other healthcare professionals with a concise and structured approach to assessing and managing patients with multiple injuries, using a common lexicon to move through the protocols.

Over time, both the course content and modes of delivery have evolved to meet the varied needs of the learners. In the 11th Edition, significant care and thought have been invested in recommendations that adapt or "flex" care when resources or practice settings differ from the original recommendations. This recognition of essential adaptability honors the continued adoption of ATLS in varied settings around the world. The principle of "Trauma Education for All" is implemented through partnerships and promulgation models designed to facilitate adoption of the course into nearly any area that seeks to improve its approach to the injured patient.

A trauma care team integrates many different healthcare professionals, and the ATLS revision team reflects that breadth across surgical and practice disciplines. The ACS Committee on Trauma is purposely inclusive to ensure the broadest engagement of interests, abilities, and lived experiences. As a result, more than 200 volunteers from nearly 20 countries and numerous specialties and disciplines contributed to this 11th Edition revision. Their thoughtful contributions and expertise, combined with innovative delivery and teaching methods have helped ensure that the entire trauma care team completes their ATLS experience with critical knowledge and skills. We are indebted to the thousands of instructors who have taught this course to more than 1.5 million learners in nearly 100 countries to date.

Collectively, these practitioners of evidence-based trauma care have pursued excellence for nearly 50 years. As you engage with the newest iteration of ATLS, you too contribute to the advancement of this enduring, vital purpose—ensuring optimal care for injured patients. Thank you and best wishes for your success.

Patricia L. Turner, MD, MBA, FACS
Executive Director & CEO
American College of Surgeons

JEFFREY D. KERBY, MD, PHD, FACS

The Advanced Trauma Life Support® (ATLS®) Course remains the gold standard for educating healthcare clinicians devoted to the care of the injured patient around the world. The Committee on Trauma (COT) has been steadfast in its commitment to continuously updating and refining ATLS education since the release of the first ATLS manual 45 years ago. This 11th Edition of the course provides significant advancement, incorporating the latest evidence-based practices and recognizing the varied resource environments where ATLS training can be applied to positively impact outcomes from traumatic injury.

Today, more ATLS Courses are taught abroad than in the US, with robust training programs that are active in nearly 100 countries around the world. In recognition of the global engagement in ATLS education, it was important that this edition of the course be intentionally inclusive of the international community to influence its content. I am proud that the COT process for development of the ATLS 11th Edition convened contributors from more than 20 different countries representing the different care and resource settings where ATLS education is provided. By continuing to provide a common "language" for multidisciplinary trauma care clinicians around the world, ATLS offers a standardized approach for optimizing the care of the injured patient that has been its core guiding principle since its inception.

Notably, while the care of the trauma patient has evolved over the years with new technological advancements, the core tenets of ATLS continue to be applicable, such as the prompt identification of injury and prioritizing and addressing immediate life threats. This 11th Edition is a fitting tribute to Dr. Styner's original vision and intent for this course. The enduring principles for caring for the injured patient in a course borne from tragedy following a tragic plane crash involving Dr. Styner and his family has become a triumph for the many that have been saved from its teachings.

I would like to thank the many surgeons, trauma care clinicians, educators, and ACS staff partners who invested their time and energy into this 11th Edition. Through countless hours of in-person meetings, teleconferences across many time zones, and individual content development, they have produced a course that models education innovation, and is both current and translatable to many different practice environments. This course provides the base educational content for caring for the injured patient, and when paired with the newly redesigned MyATLS® app for sustainment training, it will prepare frontline clinicians for the initial evaluation and stabilization of trauma patients. We are excited to share this 11th Edition with you.

Jeffrey D. Kerby, MD, PhD, FACS
Chair of the ACS Committee on Trauma

EDITORIAL NOTES

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Given the global reach of the ATLS® Course, this Edition of the ATLS Course Manual and accompanying materials may require adjustments in terminology to ensure clarity and comprehension across different regions for all learners and instructors.

The objective of the ATLS® Program is to save lives through education. Fostering a safe and productive learning environment is central to a successful educational endeavor. Engaging, learner-friendly content, such as interactive scenarios and visual aids, greatly enhances understanding and participation. Global standardized flexibility of these materials allows customization of educational content to a variety of settings while maintaining high-quality standards and best practices. This approach not only empowers healthcare professionals but also serves as a model for delivering patient care with the highest levels of respect, dignity, and excellence. Ultimately, this course provides learners with the essential knowledge and skills to apply adaptable, best practices in trauma care, promoting optimal patient outcomes for all.

ATLS is designed as an educational tool and is not intended to replace clinical judgment or to serve as a measure of clinical competence. Determining a clinician's privileges to provide care or perform procedures is the responsibility of local governing bodies, not the ACS.

Throughout this manual, the ACS Committee on Trauma will be referred to as the ACS COT or simply the Committee, while State and Provincial Chairs will be denoted as S/P Chairs.

ACS COT AND ATLS®

Founded in 1912, the American College of Surgeons (ACS) has been committed to improving the care of surgical patients, establishing itself as the foremost professional organization in North America dedicated to maintaining excellence in surgical practice. In alignment with these goals, the ACS Committee on Trauma (COT) has continually worked to enhance trauma care through the development of systems and educational programs. The ongoing advancement of the Advanced Trauma Life Support® (ATLS®) Course is a cornerstone of these efforts.

The ATLS® Course focuses on established, evidence-based methods for the treatment of trauma patients. It provides a systematic, concise approach to trauma care, one that is easily recalled and applicable in emergent situations. This methodology, which has become the hallmark of the ATLS® Course, is invaluable to clinicians responsible for treating injured patients. The principles outlined in this manual may also benefit those who care for patients with non-traumatic conditions.

Trauma patients often present with a wide range of complex and variable conditions. The ATLS Course equips clinicians with comprehensive knowledge and adaptable techniques that can be applied in diverse clinical environments, whether in a fully resourced urban hospital or an austere setting with limited resources. The manual outlines safe and effective ways to approach the initial evaluation and management of the injured patient, ensuring that clinicians can provide competent care in a variety of contexts.

The ACS acknowledges that there are multiple valid approaches to medical care and procedures in this context. Each clinician must use their own judgment in applying ATLS principles to individual patients, considering their own experience and local standards of practice. The knowledge and skills imparted by the ATLS® Course are designed to be applicable and relevant across different clinical settings and a wide range of environments.

To remain current with evolving medical knowledge and innovations in trauma care, the ATLS® Course is regularly revised. These revisions incorporate new techniques and safer approaches to care. The ACS COT is grateful for the invaluable contributions made by ATLS® clinicians, instructors, coordinators, and educators worldwide, whose outstanding input have been essential to the continual improvement of the course and trauma care.

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This Eleventh Edition of the Advanced Trauma Life Support® (ATLS®) Manual was developed through the collaborative efforts of dedicated members of the ACS COT, volunteer Fellows of the ACS, members of the international ATLS community, and various nonsurgical consultants. Each of these individuals generously contributed their time and expertise in trauma care and medical education. The global scope of this project, which brought together individuals from diverse contexts united by a shared mission to improve trauma care, is a testament to the ATLS family's remarkable commitment to the welfare of humanity. We extend our heartfelt appreciation to the families, significant others, children, and practice partners of ATLS instructors and participants. Their support has been integral to the program's success, allowing clinicians to dedicate time away from homes and practices to enhance their skills in trauma care. Without these sacrifices, the ATLS Course could not exist at the level of excellence it has achieved.

Additionally, the Steering Committee gratefully acknowledges the dedicated ACS COT Trauma Education staff, both past and present, for their invaluable contributions. Their leadership and expertise in various areas such as adult learning principles, instructional design, graphic design, video production, project management, learner assessment, and program evaluation are crucial to the continued success and innovation of the ATLS Course.

SPECIAL ACKNOWLEDGEMENT

The Steering Committee, along with contributors, ATLS® friends and family, and the ACS COT staff, expresses our deepest gratitude to Kathryn Bastion Strong. Known affectionately as Katie, she embodied a relentless passion for trauma education and the ATLS® Course. Katie's vision and commitment extended far beyond the traditional boundaries of education. She was a bridge-builder, uniting people from diverse backgrounds and cultures, always seeking to expand the ATLS family to new frontiers.

Katie's energy, warmth, and positive outlook were infectious. She approached every challenge with a constructive attitude, fostering collaboration and innovation among her colleagues. Her contributions were instrumental in launching the 11th Edition revision process, and her unwavering belief in the importance of trauma care education continued to inspire all of us throughout the development of this edition.

Katie's legacy is felt in every page of this manual. She would be proud to see how the program continues to evolve, expanding its reach and impact globally. Her spirit lives on in the work we do, and we are profoundly thankful for the energy and dedication she brought to this endeavor.

Thank you, Katie. Your light continues to guide and inspire.

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PREFACE TO THE ELEVENTH EDITION

The ATLS® Course establishes an organized and systematic approach for evaluation and treatment of patients, promotes standards of care, and recognizes injury as a global healthcare challenge. The approach is easily remembered by any clinician, irrespective of practice specialty and experience, and can be rapidly recalled under the stress, anxiety, and intensity of the trauma resuscitation process. ATLS provides a common language for all clinicians that facilitates team and transfer communication.

The course offers learners a foundation for evaluation, treatment, education, and quality assurance, introducing a system of trauma care that is measurable, reproducible, and comprehensive. The ATLS Program has had a positive impact on the care of injured patients worldwide. This effect is a result of the improved skills and knowledge of course participants and promotion of trauma system development. Over an almost half-century of ATLS instruction and revisions, course content has evolved as techniques, technology, and the science of traumatology have advanced. Moving forward, the ATLS Program will continue to refine its content to meet the needs of the many clinicians involved in the care of the trauma patient.

ELEVENTH EDITION REVISION PROCESS

The 11th Edition revision process maintained the global participation and positive direction of prior versions. Through multiple meetings with ATLS® subcommittee members and surgical education experts, a typical ATLS learner was defined. This learner is beginning their journey in emergency trauma care, frequently serving as a clinician outside of a level 1 Trauma Center. However, clinicians practicing in an advanced center will also benefit from the knowledge and skills transmitted in ATLS.

Every aspect of the course was reviewed and revised, including this manual, interactive discussion materials, skills station curricula, online modules, video resources, initial assessment stations, multiple-choice test questions, MyATLS® app content, and policies. All aspects were recreated to meet the needs of the ATLS learner and to adhere to the best medical and educational evidence available. As the field of traumatology has expanded markedly since the inception of ATLS, the risk of cognitive overload was recognized and mitigated. Although new content was added, an increase in course length was avoided by attention to objectives, integration of concepts, and provision of pre-course materials.

Twenty-four content areas were identified. Global trauma leaders, representing more than 20 countries, volunteered and were distributed among the content areas to provide a diverse perspective on each topic. A surgical educator was a key member of each team. These workgroups met frequently and developed new learning objectives for each content area. Product leads translated these goals to create each ATLS Course product.

ATLS® clinicians treat patients in a wide variety of practice environments. Some are at facilities with seemingly unlimited continuous access to personnel, blood products, specialty care, and advanced technology. Others are at facilities where access to diagnostics, specialists, blood products, and medications is limited or never available. Various local, state, regional, provincial, and national agencies regulate medical practices. In recognition of these variations in practice settings and resources, the concept of standardized flexibility was developed to promote adaptability of ATLS Course content. A *Flex* workgroup was formed. They reviewed all materials through the lens of resource availability and ensured that the ATLS Course would be applicable to a wide variety of practice environments.

ATLS learners are members of a multitude of cultures and backgrounds. To be successful, an educational program must foster an environment conducive to learning that includes safe and impactful terms, wording, and images in all products. For effective transfer of the life-saving knowledge, skills, and attitudes of ATLS, every learner must be able to visualize themselves as an accepted member of the course. Therefore, another workgroup examined materials for application across varied cultures to promote learning and ensure content and delivery are relevant to all ATLS learners.

CHANGES IN COURSE STRUCTURE AND CONTENT

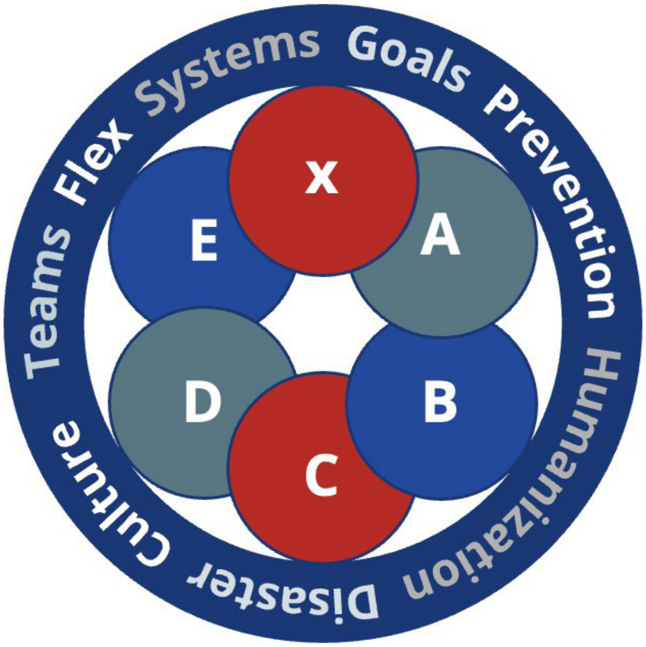
Treat the greatest threat to life first remains the central tenet of the ATLS mnemonic. This threat is determined by the specifics of the clinical situation. For certain patients, rapid control of exsanguinating external hemorrhage is lifesaving. Military and civilian research has validated application of this approach before initiating airway maneuvers in appropriate clinical contexts. Therefore, the letter *x* was added at the beginning of the well-known ATLS mnemonic. ABCDE is now *xABCDE*.

Injury and injury care occur within environments that extend beyond the boundaries of the medical facility and beyond the limits of physical interventions. Opportunities for injury prevention and trauma system development may be recognized by the events of patient injury. A holistic approach recognizes the dignity and value of every individual and is mandatory to obtain optimal outcomes. Effective communication within the care team, to the patient and family members, and during transfer prevent morbidity and mortality.

Even an introductory discussion of each topic applicable to acute management of the injured patient would overwhelmingly increase ATLS Course length and induce cognitive overload. Therefore, topics have been integrated like they occur in clinical practice, wrapped within the context of an injured patient. ATLS® refers to this integration of physical, communication, holistic, prevention, systems, and other aspects of clinical interaction as the *weave* concept. ■ **Figure 1** illustrates the *weave* concept.

In the 10th Edition, skills stations were successfully reorganized into Airway, Breathing, Circulation, and Disability to promote practice and retention of the critical *ABCDE* mnemonic. In this 11th Edition, reorganization is extended to the entire course to enhance learner cognition and performance of *xABCDE* during initial assessment.

■ **Figure 1: Content Weave.** During interactive discussions, online modules, skills station scenario discussions, and other aspects of the ATLS® Course, the concepts of xABCDE (x, control of external exsanguinating hemorrhage; A, Airway; B, Breathing; C, Circulation; D, Disability; E, Exposure and environment) are reinforced and topics of trauma systems, communicating serious news and goals of care, injury prevention, humanization (patient-centered care), disaster events, cultural appropriateness, teamwork, and flexible options in practice environments are presented within a clinical story.



This manual is organized into three major sections. Section I is titled *Evaluation, Management, and Resuscitation of the Injured Patient*. This first section includes subjects related to initial assessment, both primary and secondary surveys. The *xABCDE* topics are extensively discussed along with team function, communication, thermal injury, special populations, musculoskeletal trauma, and transfer.

Control of exsanguinating hemorrhage is addressed as a separate topic. Airway instruction has added emphasis on resuscitation of patients in shock prior to administration of medications for intubation. Most subjects discussed in the 10th Edition *Thoracic Trauma* chapter are included in *Breathing and Ventilation Assessment and Management* with others transitioned to a new *Thoracic, Abdominopelvic, and Genitourinary Trauma* chapter. The importance of pain management in thoracic injury is emphasized. Content from the 10th Edition *Shock* chapter is present and expanded in *Circulation Assessment and Volume Resuscitation*. The 10th Edition topics of *Head Trauma* and *Spine and Spinal Cord Trauma* are addressed in a combined *Disability: Neurological Assessment and Management* chapter. *Exposure and Environmental Threats in the Primary Survey* moves the subjects of *Hypothermia and Heat Injuries* from the appendices.

The critical importance of team dynamics and communication is recognized with relocation from a 10th Edition appendix to an expanded Section I chapter titled *Resuscitation Team Function and Communication*. Volume resuscitation for burn injury follows American Burn Association recommendations. *Geriatric Trauma* is renamed *Trauma in the Older Adult* and expanded to reflect the increasing importance of injury and frailty in this vulnerable population. An updated transfer communication mnemonic of *S-xABCDE-BAR* is introduced in *Transfer to Definitive Care*.

Section II covers many of the *weave* subjects. *Trauma Systems* is an entirely new chapter that introduces the topic to ATLS® learners. Concepts related to triage and disaster management are moved from appendices to an expanded chapter. Three new chapters, *Injury Prevention*, *Trauma-Informed Care and Social Determinants of Health*, and *Communicating Serious News in the Acute Setting* address these critical subjects in trauma care.

Section III includes topics on specific injuries and injury patterns. *Thoracic, Abdominopelvic, and Genitourinary Trauma* reviews specific injuries not previously discussed and updates on topics that were present in the 10th Edition *Abdominal and Pelvic Trauma* chapter. *Penetrating Trauma* is a new chapter providing education regarding unique management challenges of these injuries. Both *Ocular Injuries* and *Injury in Combat Zones and Austere Environments* were updated and moved from the appendices.

UPDATES TO INTERACTIVE DISCUSSION SESSIONS AND ONLINE MODULES

Corresponding to the manual rearrangement, the interactive sessions follow the progression of the Section I titles. All materials have been rewritten and redesigned with updated cases, images, and instructor notes. Standardized flexibility permits instruction that best serves the local practice resources.

The ATLS Hybrid Course has been extremely successful since initial release. In many centers it is the primary format for ATLS instruction. The program provides self-paced interactive instruction designed as an educational substitute for many of the in-person interactive discussions. Learners complete all designated modules before arriving for in-person group discussions, skills training, and course assessments, shortening the in-person portion of the ATLS Course. The Hybrid ATLS program increases flexibility for the learners and training centers while providing similar training.

The 11th Edition Hybrid ATLS is a redesign and redevelopment of the ATLS online modules. An amazing team of instructional design professionals developed the modules based on the interactive discussion materials. Thus, the modules more closely mimic an in-person course and provide an educationally equivalent experience. Learning is enhanced with up-to-date, evidence-based interactivity and learning methods. Design is consistent and more appealing to the learner. Modules utilize multiple methods of interaction, employing current best practices in instructional design. Following the concept of standardized flexibility, optional modules were developed that deliver instruction on material in manual Sections II and III.

CHANGES IN SKILLS STATIONS AND VIDEO RESOURCES

Skills Stations in the 11th Edition have a similar organization to those of the 10th Edition. The stations are organized along the *xABCDE* mnemonic. All materials were re-created and include integrated supply lists and instruction slide sets.

Practice is important to the success of ATLS skill instruction. However, time constraints present challenges to providing quality evidence-based stepwise training. The 11th Edition takes an innovative path to improve skills training. The six steps in technical skill acquisition are: know (cognition), see (visualization), hear (instructor verbalization), say (learner verbalization), do (practice), and review (feedback). The 11th Edition relocates performance of the first three steps (know, see, and hear) from the in-person skills stations to pre-course learning. This relocation was accomplished by creation of new mandatory pre-course video resources to clearly introduce specific skills. Thus, in-person skills stations are primarily devoted to practice and feedback.

New for the 11th Edition is standardized flexibility in skill options. The Airway station may focus on intubation or, for localities when intubation is limited to certain specialty clinicians, management prior to intubation. Space is provided in the schedule for optional stations to meet local educational needs such as burn resuscitation or an enhanced pediatric experience. Management of prehospital tourniquets and tourniquet conversion has been added. Triage and disaster management is completely reimagined and follows the principles of the Disaster Management and Emergency Preparedness course.

CHANGES IN LEARNER ASSESSMENT

A global workgroup of experts in the construction of multiple-choice questions was formed. This workgroup developed a new bank of questions based on this manual and the objectives developed by the content groups. These questions were vetted by several groups for appropriateness. Revised initial assessment patient scenarios with critical treatment decisions were constructed based on the new *xABCDE* mnemonic and other content changes.

MYATLS® APP

The MyATLS® mobile app was redesigned and redeveloped to provide an enhanced user-friendly learning experience. It allows easy access to critical trauma care information in the form of chapter summaries, videos, step-by-step skill guides, medical calculators, and checklists. New practice features have been added, including quiz questions, flashcards, and interactive case scenarios. The new content management system allows for easy edits to existing content and enables new content to be added on a regular basis.

ATLS decision-making tools and content can be in the clinician's pocket. The MyATLS mobile app can be found in the Apple Store and Google Play by searching for "ACS MyATLS." For additional information visit www.facs.org/myatls.

COURSE OVERVIEW

COURSE GOALS

The content and skills presented in this course are designed to assist clinicians in providing emergency care for trauma patients. Though the concept of the *golden hour* is not a fixed period of 60 minutes, it emphasizes the urgency necessary for successful treatment of injured patients. This concept symbolizes the positive impact of rapid assessment and proper management on the morbidity and mortality associated with injury. The ATLS® course provides the essential information and skills for clinicians to identify and treat life-threatening and potentially life-threatening injuries under the extreme intellectual and emotional pressures associated with the care of these patients. The ATLS Course is applicable to clinicians in a variety of situations. The ATLS Course supplies its learners with a safe and reliable method for the immediate treatment of injured patients and the basic knowledge necessary to:

- Assess a patient's condition rapidly and accurately.
- Resuscitate and stabilize patients according to priority.
- Determine whether the specific management needs of a patient exceed the resources of a facility and/or the capability of a clinician.
- Arrange appropriately for a patient's interhospital or intrahospital transfer.
- Ensure that optimal care is continually provided, and the level of care does not deteriorate at any point during evaluation, resuscitation, or transfer.

COURSE OBJECTIVES

Upon completing the ATLS Course, the participant will be able to:

- Practice the concepts and principles of initial assessment through the primary and secondary patient surveys.
- Establish management priorities in a simulated trauma situation.
- Initiate primary and secondary management necessary for the emergency management of acute life-threatening conditions in a simulated patient.
- Apply the key principles of effective team function and communication in a simulated trauma scenario.
- Practice primary and secondary initial assessment surveys of a patient with simulated injuries.
- Perform control of simulated life-threatening external hemorrhage.
- Evaluate and manage airway patency and initiate assisted ventilation in a simulated trauma patient.
- Demonstrate the procedure of surgical/incisional airway.
- Identify clinical and radiographic signs of thoracic injuries.
- Describe the steps for a needle or finger thoracostomy and chest tube insertion for pleural decompression in a simulated scenario.

- Assess and treat a simulated patient in shock with recognition of life-threatening hemorrhage.
- Perform intraosseous access in a simulated patient.
- Apply an external pelvic compression device for hemorrhage due to pelvic fracture in a simulated trauma patient.
- Evaluate the abdomen for hemorrhage with either peritoneal lavage or ultrasound (FAST).
- Evaluate and treat a simulated patient with brain injury, including use of the Glasgow Coma Scale score.
- Demonstrate protection of the spinal cord and radiographic and clinical evaluation of spine injuries in a simulated trauma scenario.
- Perform musculoskeletal trauma assessment and management in a simulated scenario.
- Apply the principles of trauma assessment of simulated older adults, pediatric patients, and pregnant patients.

COURSE STRUCTURE

The ATLS Course emphasizes application of new knowledge and skills. Application leads to acquisition. Instruction occurs in a variety of venues: self-study, small groups, and larger groups. Didactic material is primarily supplied in this manual. Application of didactic knowledge occurs through interactive discussions and online modules. Cognitive and psychomotor skills are introduced and practiced in the skills stations. A variety of artificial, inanimate, and animate models may be employed as determined by the teaching center. Initial patient assessment stations provide opportunities to practice primary and secondary survey procedures. Live actors, mannikins, and other simulations may be used.

For successful ATLS Course completion, at minimum the learner is required to:

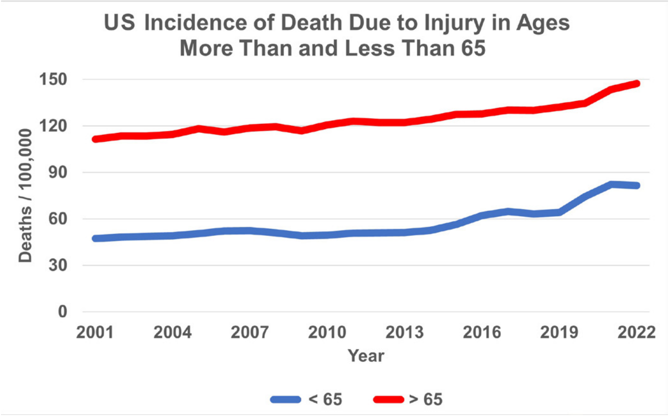
- Complete all pre-course materials including a pretest and visualization of all videos. Specific centers may have other pre-course requirements.
- For ATLS Hybrid Courses, complete all modules prior to the in-person portion of the course. The timeframe for completion is determined by the center.
- Attend the entire in-person portion of the course per the center's schedule.
- Actively participate in all interactive discussions.
- Successfully perform all core psychomotor and cognitive skills as assessed by an ATLS instructor and/or Course Director.
- Reach a passing grade on a multiple-choice examination.
- Perform at an adequate level on an evaluation initial assessment scenario simulation as determined by an ATLS instructor and/or Course Director.
- Demonstrate appropriate skills, knowledge, and attitudes throughout the ATLS Course.
- Demonstrate appropriate professional conduct and fulfill any other requirements as described in the ATLS policy manual, other statements, or as determined by ATLS directors and offices.

NEED FOR ATLS® -THE GLOBAL EPIDEMIC OF TRAUMA

The social and economic impact of injury is staggering. Even during the two years of the COVID-19 pandemic, unintentional injury was the fourth-leading cause of death in the United States according to data from the CDC. For the most recent year of data, 2022, unintentional injury returned to the third-leading cause of death, trailing only cardiovascular disease and malignancy. Unintentional injury remains the leading cause of death for ages 1-44, third leading for ages 45-65, and in the top eight beyond age 65.

Despite markedly improved prevention and medical care, the prevalence of death due to injury in the US rose from 2001 to 2022. Injury is frequently viewed as more prevalent in a younger population. However, injury deaths in those older than 65 have also been rising as illustrated in ■ **Figure 2**. The percentage of injury deaths due to falls in the older population has increased from approximately 30% in 2001 to almost 50% in 2022. Overall, for all age groups, suicide deaths have doubled, and homicides have remained relatively unchanged in the same time period.

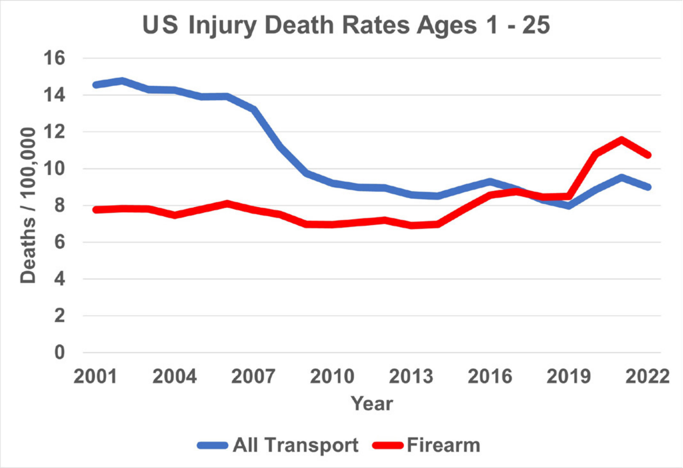
■ **Figure 2: US Incidence of Death Due to Injury in Ages More Than and Less Than 65.** Rates are reported as deaths per 100,000. Rising incidence of death from all injury etiologies in both age groupings. Age less than one year excluded.



Institute for Health Metrics and Evaluation (IHME). GBD Compare Data Visualization. Seattle, WA: IHME, University of Washington, 2024. Available from http://vizhub.healthdata.org/gbd-compare. (Accessed October 16, 2024).

To place the magnitude of death due to injury in perspective, during 2020 and 2021 deaths due to injury were 58-fold higher than deaths due to HIV and equal to approximately 75% of the deaths due to COVID-19. Thus, from a purely mathematical standpoint, injury mortality in the US is like a COVID-19-severity epidemic every 16 months. Strikingly, since 2018, firearm injuries surpassed transport-related injuries as a leading cause of death in ages 1 to 25. ■ **Figure 3** illustrates this change.

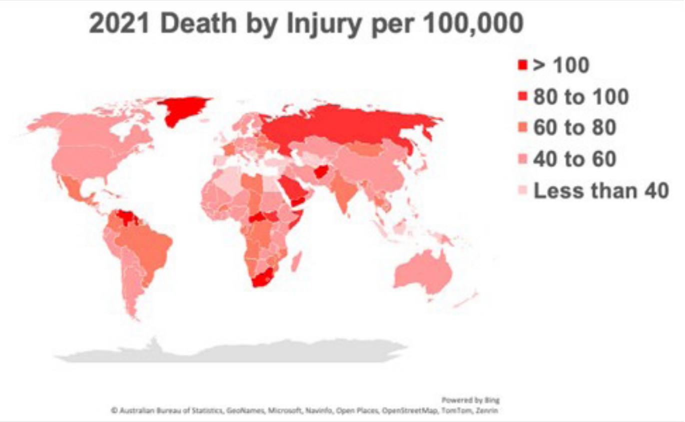
■ Figure 3: US Injury Death Rates for Ages 1 – 25. Rates are reported as deaths per 100,000 and include intentional and unintentional injuries. The blue line depicts all transport-related deaths excluding drowning-associated deaths. Red line depicts all firearm-related deaths.



Institute for Health Metrics and Evaluation (IHME). GBD Compare Data Visualization. Seattle, WA: IHME, University of Washington, 2024. Available from http://vizhub.healthdata.org/gbd-compare. (Accessed October 16, 2024).

According to the World Health Organization (WHO), more than eight people die every minute from injuries or violence. This is approximately 4.4 million deaths per year from all ages and economic groups. **■ Figure 4** illustrates estimated total injury death rates by country as of 2021. Road traffic injuries are the leading cause of death for ages 5–29. According to the WHO, low- and middle-income countries have about 60% of the world's vehicles, yet 93% of deaths occur in these countries.

■ Figure 4: 2021 Estimated Injury Deaths per 100,000.


2021 Death by Injury per 100,000
■ > 100
■ 80 to 100
■ 60 to 80
■ 40 to 60
■ Less than 40
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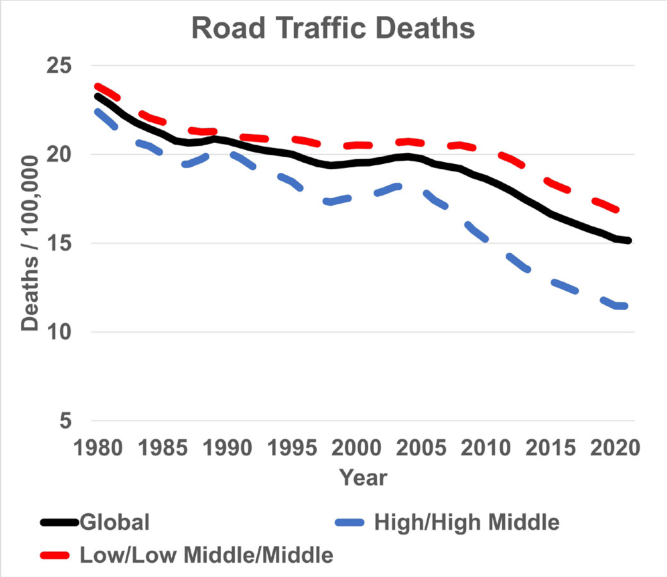
Institute for Health Metrics and Evaluation (IHME). GBD Compare Data Visualization. Seattle, WA: IHME, University of Washington, 2024. Available from http://vizhub.healthdata.org/gbd-compare. (Accessed October 16, 2024).

Injury occurs in younger age groups and the economic impact is astounding. For 2019, the U.S. estimated total lifetime costs for medical care, lost productivity, lost quality of life, and loss of life was $4.2 trillion or 19% of the US GNP. For perspective, the entire US Government budget for 2023 was $7.6 trillion. The estimated cost for injury is close to the combined amount the US government budgeted for Medicare, Social Security, Defense, and Health in 2023.

Multifaceted prevention efforts have decreased the global rate of road traffic fatalities. These efforts include legislation, safer vehicles, improved restraint systems, road construction and design, education, and improved medical care. Although all economic groups have experienced a reduction in death rates, the magnitude of improvement is less in lower-income economies. As illustrated in **■ Figure 5**, more affluent nations have experienced a nearly 50% reduction in the incidence of road traffic fatalities while the less-prosperous nations have experienced only a 30% improvement from 1980 to 2022.

■ Figure 5: Road Traffic Deaths. Incidence of road traffic fatalities globally and distributed into higher and lower economic groups. Solid line is the global rate. Red line is the rate for low-, low-middle-, and middle-income nations combined and population weighted. Blue line represents the combined and population-weighted incidence for high- and high-middle income nations.



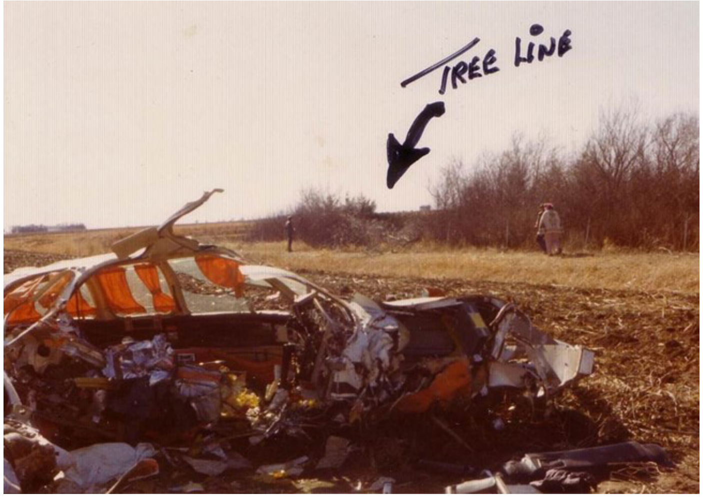
Institute for Health Metrics and Evaluation (IHME). GBD Compare Data Visualization. Seattle, WA: IHME, University of Washington, 2024. Available from http://vizhub.healthdata.org/gbd-compare. (Accessed October 12, 2024).

ATLS® HISTORY, DEVELOPMENT, AND GLOBAL DISSEMINATION

TRAGEDY AND CHALLENGE

In February 1976, a tragedy occurred that directly led to improved global trauma care. Dr. James K. Styner, MD, FACS, an orthopaedic surgeon and pilot, was flying his family home from California to Lincoln, Nebraska. In poor weather with reduced visibility, the plane struck a row of trees and crash landed in a rural Nebraska cornfield. ■ **Figure 6** is a photo of the crash site. Dr. Styner's wife, Charlene, was ejected and died instantly. Dr. Styner sustained serious injuries. Three of their children suffered critical injuries, and another sustained minor injuries.

■ **Figure 6: Photograph of 1976 Plane Crash.**



Despite his own painful injuries, Dr. Styner extricated his children from the plane and walked to a road in search of help. Eventually, he was able to stop a passing car and obtain assistance. Dr. Styner and his children were driven to the local hospital. However, the doors were locked. Although physicians ultimately arrived and the Styner family was transferred to Lincoln, Dr. Styner was dissatisfied with the timeliness and quality of care that he and his family received. It was inadequate by the day's best standards.

After taking time to recover from his loss and the physical and mental injuries suffered by himself and his children, Dr. Styner repeatedly questioned the inconsistent state of early injury care in the United States. He is quoted as saying, "When I can provide better care in the field with limited resources than what my children and I received at the primary care facility, there is something wrong with the system, and the system has to be changed."

Dr. Ronald Craig, a family medicine specialist who was a friend and treating physician of the Styners, responded by noting, "You have to train them before you blame them." Dr. John Upright, PhD, EdD, director of the Lincoln Medical Education Fellowship (LMEF), encouraged Drs. Styner and Craig. They began to develop a trauma care protocol rooted in emerging data, simplicity, and practicality. The importance and relevance of the project were recognized by many at Lincoln General Hospital. Soon, a multispecialty panel of private practice physicians, nurses, and educators joined the group, including Irvene Collicott, RN, (née Hughes), Lincoln Area Mobile Heart Team nurses, and the LMEF.

A NEW WAY TO THINK

Prior to ATLS®, medical schools taught the same approach to be used to treat injured patients and patients with any other undiagnosed medical condition. An extensive history of present illness and past medical history was followed by a head-to-toe physical examination. Once a differential list was created, studies were performed to uncover the diagnosis. When all pertinent laboratory and imaging studies were completed and reported, treatment was finally initiated. Although this approach was usually adequate in most situations, it did not satisfy the needs of patients suffering immediately life-threatening injuries. The approach required change. Clinicians needed a new way to think.

The group identified three revolutionary underlying concepts that have stood the tests of time, practical application, and medical advances:

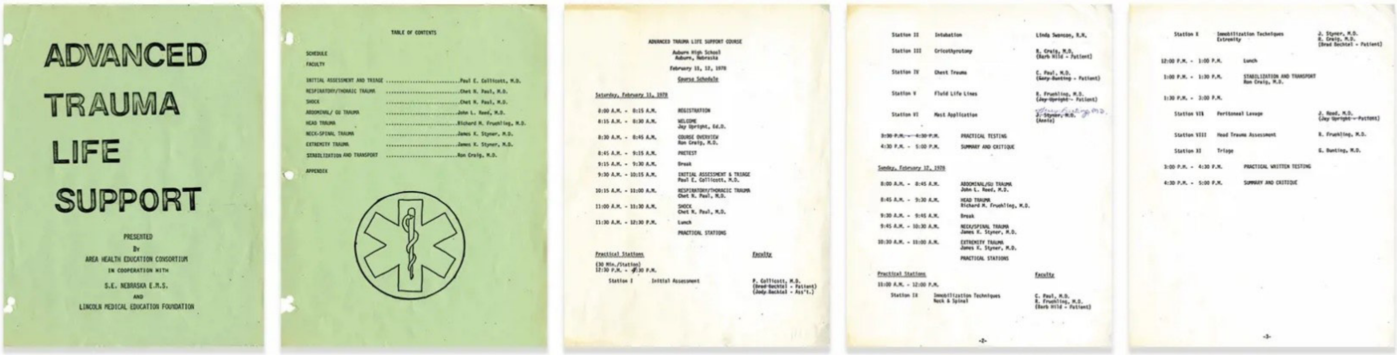
- Treat the greatest threat to life first.
- Never allow the lack of definitive diagnosis to impede the application of an indicated treatment.
- A detailed history is not essential to begin the evaluation of a patient with acute injuries.

Experience from large centers in the late 1970s indicated that injury mortality occurred in certain reproducible time frames. For example, the loss of an airway killed more quickly than the loss of the ability to breathe. The latter caused death more quickly than internal loss of circulating blood volume. The presence of an expanding intracranial mass lesion may be the next most lethal problem. Based on data and expert opinions at the time, a simple recall method, ABCDE, was created to remember the specific ordered evaluations and interventions to be followed:

- Airway with restriction of cervical spine motion
- Breathing
- Circulation, stop bleeding
- Disability or neurologic status
- Exposure (undress) and Environment (temperature control)

Applying principles of adult education, the group set forth to develop a course geared to primary care physicians who do not manage multiply injured patients on a frequent basis. This new educational program combined didactic sessions, skill practice, and simulation. With the help of Southeast Nebraska Emergency Medical Services, the first course was delivered in February 1978 and a second course shortly after. Both courses were successfully conducted in rural Nebraska hospitals with positive feedback. ■ **Figure 7** illustrates the first ATLS manual.

■ **Figure 7: Pages from First ATLS® Manual with Course Schedule.**



ADVANCED
TRAUMA
LIFE
SUPPORT

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By
AREA HEALTH EDUCATION CONSORTIUM
IN COOPERATION WITH
S.E. NEBRASKA E.M.S.
AND
LINCOLN MEDICAL EDUCATION FOUNDATION

TABLE OF CONTENTS

SCHEDULE
FACULTY
INITIAL ASSESSMENT AND TRIAGE ....Paul E. Collicott, M.D.
RESPIRATORY/THORACIC TRAUMA ....Chet H. Paul, M.D.
SHOCK ....Chet H. Paul, M.D.
ABDOMINAL/ GU TRAUMA ....John L. Reed, M.D.
HEAD TRAUMA ....Richard M. Fruehling, M.D.
NECK-SPINAL TRAUMA ....James K. Styner, M.D.
EXTREMITY TRAUMA ....James K. Styner, M.D.
STABILIZATION AND TRANSPORT ....Ron Craig, M.D.
APPENDIX

ADVANCED TRAUMA LIFE SUPPORT COURSE
Auburn High School
Auburn, Nebraska
February 11, 12, 1978
Course Schedule

Saturday, February 11, 1978

8:00 A.M. - 8:15 A.M. REGISTRATION
8:15 A.M. - 8:30 A.M. WELCOME Jay Upright, Ed.D.
8:30 A.M. - 8:45 A.M. COURSE OVERVIEW Ron Craig, M.D.
8:45 A.M. - 9:15 A.M. PRETEST
9:15 A.M. - 9:30 A.M. Break
9:30 A.M. - 10:15 A.M. INITIAL ASSESSMENT & TRIAGE Paul E. Collicott, M.D.
10:15 A.M. - 11:00 A.M. RESPIRATORY/THORACIC TRAUMA Chet H. Paul, M.D.
11:00 A.M. - 11:30 A.M. SHOCK Chet H. Paul, M.D.
11:30 A.M. - 12:30 P.M. Lunch
PRACTICAL STATIONS

Practical Stations — Faculty
(30 Min./Station)
12:30 P.M. - 3:30 P.M.
Station I Initial Assessment — P. Collicott, M.D. ~~(Brad Bechtel - Patient)~~ ~~(Jody Bechtel - Ass't.)~~

Station II Intubation — Linda Swanson, R.N.
Station III Cricothyrotomy — R. Craig, M.D. (Barb Hild - Patient)
Station IV Chest Trauma — C. Paul, M.D. ~~(Gary Bunting~~ - Patient)
Station V Fluid Life Lines — R. Fruehling, M.D. ~~(Jay Upright~~ - Patient)
Station VI Mast Application — ~~J. Styner, M.D.~~ [illegible] (Annie)

~~3:30 P.M. - 4:30 P.M.~~ PRACTICAL TESTING
4:30 P.M. - 5:00 P.M. SUMMARY AND CRITIQUE

Sunday, February 12, 1978

8:00 A.M. - 8:45 A.M. ABDOMINAL/GU TRAUMA John L. Reed, M.D.
8:45 A.M. - 9:30 A.M. HEAD TRAUMA Richard M. Fruehling, M.D.
9:30 A.M. - 9:45 A.M. Break
9:45 A.M. - 10:30 A.M. NECK/SPINAL TRAUMA James K. Styner, M.D.
10:30 A.M. - 11:00 A.M. EXTREMITY TRAUMA James K. Styner, M.D.
PRACTICAL STATIONS

Practical Stations — Faculty
11:00 A.M. - 12:00 P.M.
Station IX Immobilization Techniques Neck & Spinal — C. Paul, M.D. R. Fruehling, M.D. (Barb Hild - Patient)

-2-

Station X Immobilization Techniques Extremity — J. Styner, M.D. R. Craig, M.D. (Brad Bechtel - Patient)

12:00 P.M. - 1:00 P.M. Lunch
1:00 P.M. - 1:30 P.M. STABILIZATION AND TRANSPORT Ron Craig, M.D.
1:30 P.M. - 3:00 P.M.
Station VII Peritoneal Lavage — J. Reed, M.D. ~~(Jay Upright - Patient)~~
Station VIII Head Trauma Assessment — R. Fruehling, M.D.
Station XI Triage — G. Bunting, M.D.
3:00 P.M. - 4:30 P.M. PRACTICAL WRITTEN TESTING
4:30 P.M. - 5:00 P.M. SUMMARY AND CRITIQUE

-3-

THE TAKE OFF

In the fall of 1978, the immediate past Chair of the COT and the current President of the American College of Emergency Physicians were both from Nebraska. The new COT Chair was from Oklahoma. During the weekend of the Oklahoma - Nebraska college football game, these leaders were able to observe an ATLS® Course. At the next spring COT meeting in Houston, a COT member surgeon from Lincoln, Dr. Paul "Skip" Collicott, MD, FACS, introduced the concept of ATLS® to the COT leadership. Later that year, a course was conducted in Lincoln for the US COT Region Chiefs. The course was adopted by the ACS Board of Regents in 1980. With this ACS and COT support, ATLS was rapidly and enthusiastically disseminated nationally that year through the infrastructure of the COT regional committees.

GLOBAL ADOPTION

In 1981, Toronto and Vancouver hosted ATLS Courses. As a pilot project, the ATLS Course was presented outside of North America in 1986 in the Republic of Trinidad and Tobago. The ACS Board of Regents gave permission in 1987 for promulgation of the ATLS Course in other countries. Members of the Royal College of Australasia attended a course in San Diego, CA, in 1987. This group and others developed the infrastructure to manage the course. Courses were held in Melbourne and Sydney in 1988, supported by both Australian and US faculty. Also in 1988, ATLS expanded to Europe through the UK Royal College of Surgeons.

The principles of ATLS were rapidly accepted by the global community. Within 15 years, courses had been delivered on six continents. With growing interest in ATLS outside of North America, the COT recognized that to have a more significant impact on trauma care worldwide, global regional leadership was necessary. Therefore, new regions were added to the COT structure.

These regions promulgated ATLS® within defined areas of global responsibility, extending the life-saving program into regions distant from North America. Currently, more than half of all ATLS® instruction occurs outside North America and these are the fastest-growing ATLS regions. Introduction of the ATLS® course may be requested by a recognized surgical organization or ACS Chapter in another country by corresponding with the COT Trauma Education Office, Chicago, Illinois.

Although professional medical educators have been part of ATLS Course design and revision since the beginning, their special value was formalized with creation of the Senior Educator Advisory Board (SEAB) in 2010. SEAB members come from all regions of the COT, creating a group with worldwide knowledge and understanding of cultural impact on learning. Critically important to high quality of ATLS Courses are high-quality instructors. The ATLS Instructor Course provides instructor candidates with the opportunity to learn educational theory, actively apply it within the ATLS Course, and achieve ATLS instructor status.

In parallel with the ATLS Course is the Prehospital Trauma Life Support (PHTLS) Course, sponsored by the National Association of Emergency Medical Technicians (NAEMT). The PHTLS course, developed in cooperation with the ACS COT, is based on the concepts of the ACS ATLS Course and is conducted for emergency medical technicians, paramedics, and nurses who are clinicians of prehospital trauma care. The Society of Trauma Nurses offers Advanced Trauma Care for Nurses (ATCN), which is also developed in cooperation with the ACS COT. The ATCN and ATLS Courses are conducted in parallel. Nurses audit the ATLS didactic sessions and then participate in separate skills stations. The benefits of having both prehospital and in-hospital trauma personnel speaking the same language are obvious.

ATLS IMPACT

ATLS training in a developing country has resulted in a decrease in injury mortality. Lower-per-capita rates of deaths from injuries are observed in areas where clinicians have ATLS training. In one study, a small trauma care team led by a doctor with ATLS experience had equivalent patient survival when compared with a larger team with more doctors in an urban setting. In addition, there were more unexpected survivors than fatalities. There is abundant evidence that ATLS training improves knowledge base, psychomotor skills, application of skills in resuscitation, and the confidence and performance of clinicians. The organizational and procedural skills taught in the course are retained by course participants for at least 6 years, which may be the most significant impact.

SUMMARY

Starting from a personal tragedy and one death, ATLS has impacted millions. The course has evolved from a typewritten manual conceived on a dining room table to a global workforce delivering and revising high-quality, evidence-based, and multimedia in-person and hybrid courses. Each year the number of courses and participants increases and, so far, more than 1.5 million clinicians have been trained around the world. ATLS materials have been translated into a multitude of languages. Innovative solutions have allowed transmission of ATLS concepts to remote, economically disadvantaged, and conflict areas with the primary goals of saving lives and reducing suffering. Although originally designed as a course for doctors, the ATLS family now includes a variety of trauma clinicians.

The ATLS method is accepted as a standard for *one safe way* of early trauma care, whether the patient is treated in an isolated rural area or a state-of-the-art trauma center. The ATLS Course emphasizes rapid assessment and concurrent treatment of severely injured patients. Care starts at the time of injury and continues through initial assessment, lifesaving interventions, reevaluation, stabilization, and, when needed, transfer. The course consists of a pre-course test, pre-course videos, online modules and or interactive discussions, scenario-driven skills stations, discussions, practice of lifesaving skills, simulations, a post-course test, and a final proficiency evaluation. Upon completing the course, participants should feel confident in implementing the cognitive and psychomotor skills taught in the ATLS Course.

TABLE OF CONTENTS

DEDICATION iii
FOREWORDS iv
EDITORIAL NOTES v
ACS COT AND ATLS® v
COT LEADERSHIP v
ATLS ELEVENTH EDITION STEERING COMMITTEE v
SENIOR EDUCATOR ADVISORY BOARD v
PAST ATLS® CHAIRS vi
ACKNOWLEDGMENTS vi
PREFACE TO THE ELEVENTH EDITION ix
COURSE OVERVIEW xi
NEED FOR ATLS - THE GLOBAL EPIDEMIC OF TRAUMA xii
ATLS® HISTORY, DEVELOPMENT, AND GLOBAL DISSEMINATION xiv

SECTION I: EVALUATION, MANAGEMENT, AND RESUSCITATION OF THE INJURED PATIENT (xABCDE) 1

Chapter 1: Initial Assessment: Primary Survey 3
Chapter 2: Resuscitation Team Function and Communication 19
Chapter 3: x: Control of eXsanguinating Hemorrhage 37
Chapter 4: Airway Assessment and Management 41
Chapter 5: Breathing and Ventilation Assessment and Management 65
Chapter 6: Circulation Assessment and Volume Resuscitation 79
Chapter 7: Disability: Neurological Assessment and Management 99
Chapter 8: Exposure and Environmental Threats in the Primary Survey 129
Chapter 9: Thermal Injuries 135
Chapter 10: Musculoskeletal Trauma 147
Chapter 11: Trauma in the Pediatric Patient 171
Chapter 12: Trauma in the Older Adult 191
Chapter 13: Trauma in the Pregnant Patient 205
Chapter 14: Initial Assessment: Secondary Survey 221
Chapter 15: Transfer to Definitive Care 233

SECTION II: TRAUMA SYSTEMS AND PATIENT-CENTERED CARE 241

Chapter 16: Trauma Systems 243
Chapter 17: Triage and Disaster Management 249
Chapter 18: Injury Prevention 257
Chapter 19: Trauma-Informed Care and Social Determinants of Health 269
Chapter 20: Communicating Serious News in the Acute Trauma Setting 279

SECTION III: SPECIFIC INJURIES AND INJURY PATTERNS – SPECIAL CONSIDERATIONS 287

Chapter 21: Thoracic, Abdominopelvic, and Genitourinary Trauma 289
Chapter 22: Penetrating Trauma 305
Chapter 23: Ocular Trauma 317
Chapter 24: Injury in Combat Zones and Austere Environments 327

SECTION I

Evaluation, Management, and Resuscitation of the Injured Patient (xABCDE)

Chapter 1: Initial Assessment: Primary Survey 3
Chapter 2: Resuscitation Team Function and Communication 19
Chapter 3: x: Control of eXsanguinating Hemorrhage 37
Chapter 4: Airway Assessment and Management 41
Chapter 5: Breathing and Ventilation Assessment and Management 65
Chapter 6: Circulation Assessment and Volume Resuscitation 79
Chapter 7: Disability: Neurological Assessment and Management 99
Chapter 8: Exposure and Environmental Threats in the Primary Survey 129
Chapter 9: Thermal Injuries 135
Chapter 10: Musculoskeletal Trauma 147
Chapter 11: Trauma in the Pediatric Patient 171
Chapter 12: Trauma in the Older Adult 191
Chapter 13: Trauma in the Pregnant Patient 205
Chapter 14: Initial Assessment: Secondary Survey 221
Chapter 15: Transfer to Definitive Care 233

1

Initial Assessment: Primary Survey

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Identify an appropriate sequence of priorities for the primary survey of injured patients using a standard algorithm
2. Describe the options and best practices for resuscitation during the primary survey
3. Describe the management techniques employed during the primary survey
4. Identify primary survey adjuncts to the assessment and management of injured patients and recognize the contraindications to their use
5. Discuss the importance of reevaluating a patient frequently during the initial assessment and how that might affect resuscitation and management
6. Recognize patients who would benefit from transfer to another facility for definitive management
7. Discuss the importance of team dynamics and communication in the initial assessment of trauma patients
8. Explain the importance of using humanistic, trauma-informed care principles when interacting with patients and families
9. Describe an approach to communicating serious news in the acute trauma setting
10. Describe the “3 Es” approach to conceptualizing injury prevention

1

Initial Assessment: Primary Survey

CHAPTER STATEMENT

The primary survey in the ATLS® initial assessment allows the clinician to identify and treat life-threatening traumatic injuries by applying a systematic approach using the eXsanguination, Airway, Breathing, Circulation, Disability, and Exposure (xABCDE) algorithm. In the setting of a critically injured patient, a specific diagnosis or complete medical history is not necessary prior to the initiation of treatment and resuscitation.

Proper execution of the primary survey also incorporates principles of high-level team functioning and communication, trauma-informed/humanistic care, resource assessment, empathetic and culturally sensitive patient/family communication, and attention to opportunities for injury prevention.

INTRODUCTION

The primary goals of the initial assessment and management of an injured patient are to identify life-threatening injuries, establish and implement treatment priorities, reevaluate patient status frequently to adjust treatment plans, and arrange for definitive care. This is done using principles of effective teamwork and by treating the patient with dignity and respect.

This chapter will examine the primary survey. Information about the secondary survey is detailed in *Chapter 14, Initial Assessment: Secondary Survey.*

Three important concepts greatly enhance the ability to manage injured patients, regardless of the environment where care is provided:

1. **Treat the greatest threat to life first.**
2. **The lack of a definitive diagnosis should not delay the application of urgent treatment.**
3. **An initial, detailed history is not essential to begin the evaluation and treatment of a patient with acute injuries.**

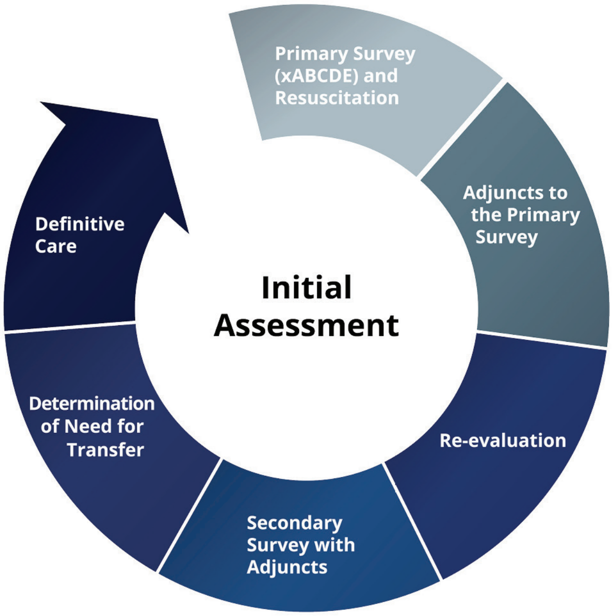
To be applicable in a global environment and assist inexperienced clinicians, ATLS follows a defined order of evaluation, recognizing that experienced trauma clinicians will frequently use the steps as a mnemonic rather than an unwavering sequence.

When treating injured patients, clinicians rapidly assess injuries and institute life-preserving therapy. Because timing is crucial, a systematic approach that can be rapidly and accurately applied is essential, and in general, life threats should be addressed when they are identified. This approach, termed the "initial assessment," includes the following elements (■ **Figure 1-1**):

- Prehospital evaluation and management
- Triage
- Preparation at the healthcare facility, including resource assessment
- Primary survey (xABCDE) with immediate resuscitation of patients with life-threatening injuries
- Adjuncts to the primary survey and resuscitation
- Reevaluation and continued post-resuscitation monitoring
- Secondary survey (head-to-toe evaluation and patient history) and adjuncts
- Determination of need for transfer
- Definitive care

The primary and secondary surveys are repeated frequently to identify any change in the patient's status that indicates the need for additional intervention. The assessment sequence presented in this chapter reflects a linear, or longitudinal, progression of events. In an actual clinical situation, however, many of these activities occur simultaneously. The longitudinal progression of the assessment process allows clinicians an opportunity to mentally review the progress of actual trauma resuscitation. ATLS principles guide the assessment and resuscitation of injured patients. Judgment is required to determine which procedures are necessary for individual patients, as not all procedures may be indicated.

■ **Figure 1-1: Elements of the Initial Assessment.** The initial assessment is a continuum that starts with the Primary and Secondary Surveys and proceeds through Definitive Care. Frequent re-evaluation throughout is critical.


Primary Survey (xABCDE) and Resuscitation
Adjuncts to the Primary Survey
Re-evaluation
Secondary Survey with Adjuncts
Determination of Need for Transfer
Definitive Care
Initial Assessment

PREHOSPITAL EVALUATION AND MANAGEMENT

In settings in which a prehospital infrastructure exists, care of injured patients is improved when prehospital personnel and institutions work together with healthcare facilities to develop protocols and expectations. Even when a formal prehospital network is lacking, healthcare facilities may work with public health systems, civic entities, or law enforcement to educate potential field responders on what care can be rendered at the scene.

The Prehospital Trauma Life Support Course, developed by the National Association of Emergency Medical Technicians in cooperation with the American College of Surgeons (ACS), is a well-established course for EMTs, paramedics, nurses, physician assistants, physicians, and other prehospital practitioners. ACS's Stop the Bleed® course trains nonmedical persons who may be immediate responders to trauma situations to perform basic bleeding control techniques. These educational activities may be useful in augmenting prehospital capabilities regardless of setting.

The ACS Committee on Trauma (COT)—with the support of the National Highway Traffic Safety Administration, Health Resources and Services Administration's Maternal and Child Health Bureau, and Emergency Medical Services for Children program—led the development of the 2021 National Guidelines for the Field Triage of Injured Patients. This document uses physiologic status, mechanism of injury, and EMS judgment to identify seriously injured patients that might benefit from care at a trauma center (■ **Figure 1-2**).

INITIAL ASSESSMENT AT THE HEALTHCARE FACILITY—PREPARATION, ASSESSMENT, AND MANAGEMENT

Witnessing the suffering of a trauma victim and facing complex care decisions are stressful and daunting situations. However, knowledge, training, and practice instill the skills and confidence to manage emotions and save lives.

Clinicians should also remember that many people have a history of prior trauma in their lives, and that this trauma may not be physical—it may be emotional, psychological, spiritual, or social. Those previous experiences can affect the way patients and families interact with the healthcare system. For example, a prior unpleasant experience in a hospital may cause anxiety or other emotions in a patient, which might be misinterpreted as noncompliance or hostility.

Preparation for the arrival of an injured patient requires organizing the team and assessing hospital resources. In the setting of a multiple or mass casualty incident, it will also require reviewing and implementing the institution's triage and disaster management procedures.

All team members should use appropriate Personal Protective Equipment (PPE) to reduce the risk of illness or injury from exposure to biological, chemical, and other hazards that might be encountered in the healthcare environment. At minimum, this should include eye and face protection, gloves, and gowns; as transpired in the recent pandemic, there may be circumstances in which more specialized equipment is necessary.

ORGANIZING THE TEAM

Preventable adverse events in trauma care may occur during the initial resuscitation and are often due to impaired situational awareness and communication failures. This reality reinforces the critical need for effective teamwork during the initial assessment. Regardless of the size and composition of the trauma team, there are five key concepts that can be applied to team function and communication:

1. Leadership and followership
2. Attention and awareness
3. Verbal communication
4. Decision-making
5. Task management and coordination

Team members, including the team leader, should have clearly assigned roles, and all team members should be able to relate information without fear of judgment.

Regularly occurring reevaluations and communication points, such as "huddles" or "time outs," can assist in this process. Important examples of these include:

- **Prearrival huddle:** In this type of communication, the known information regarding the patient is discussed and plans are formulated for how to address likely injuries, what equipment and personnel should be available, and what roles team members should assume.
- **Systematic handover at the time of patient arrival:** In this scenario, information is often communicated via a standardized process, such as the Mechanism, Injuries, Symptoms and Signs, and Treatment (MIST) tool (■ **Figure 1-3**).

When critical care is being delivered or will be immediately required (e.g., chest compressions or treatment of imminent respiratory failure), the report is delivered in an abbreviated fashion while care is delivered.

- **Huddle/reassessment at a defined point in the resuscitation:** In this scenario, a time out lead by the leader is proven to promote united mental models and team situational awareness.
- **Departure handover:** In this scenario, when the patient leaves the resuscitation area to receive definitive care, use of a systematic method of communication, such as the S-xABCDE-BAR (■ **Figure 1-4**) method, is recommended (see *Chapter 15, Transfer to Definitive Care* for additional information).

In situations in which there is no notification of patient arrival, there will obviously be no opportunity for a prearrival huddle and possibly no arrival handoff. In such situations, it is incumbent upon the team leader to quickly assign roles, verbalize initial plans, and request that all team members report clearly what they notice as the resuscitation begins. The team leader should also indicate at what juncture the first huddle/time out/reassessment will occur.

After a resuscitation is completed, the team should make every effort to conduct a debriefing to acknowledge what went well and identify opportunities for improvement. Debriefing also allows for peer support after particularly stressful resuscitations.

For more detailed information about concepts in team functioning in the acute trauma setting, see *Chapter 2, Resuscitation Team Function and Communication.*

■ **Figure 1-2: National Guideline for the Field Triage of Injured Patients.** Use of the guideline can ensure that trauma patients are transported to the most appropriate facility for treatment. Source: Newgard CD, Fischer PE, Gestring M, et al. National guideline for the field triage of injured patients: Recommendations of the National Expert Panel on Field Triage, 2021. *J Trauma Acute Care Surg*. 2022 Aug 1;93(2):e49-e60.

National Guideline for the Field Triage of Injured Patients

RED CRITERIA
High Risk for Serious Injury

Injury Patterns

- Penetrating injuries to head, neck, torso, and proximal extremities
- Skull deformity, suspected skull fracture
- Suspected spinal injury with new motor or sensory loss
- Chest wall instability, deformity, or suspected flail chest
- Suspected pelvic fracture
- Suspected fracture of two or more proximal long bones
- Crushed, degloved, mangled, or pulseless extremity
- Amputation proximal to wrist or ankle
- Active bleeding requiring a tourniquet or wound packing with continuous pressure

Mental Status & Vital Signs

All Patients
- Unable to follow commands (motor GCS score <6)
- RR <10 or >29 breaths/min
- Respiratory distress or need for respiratory support
- Room-air pulse oximetry < 90%

Ages 0-9 years
- SBP < 70 mm Hg + (2 x age in years)

Ages 10-64 years
- SBP < 90 mm Hg or
- HR > SBP

Patients meeting any one of the above RED criteria should be transported to the highest-level trauma center available within the geographic constraints of the regional trauma system.

YELLOW CRITERIA
Moderate Risk for Serious Injury

Mechanism of Injury

- High-Risk Auto Crash
  - — Partial or complete ejection
  - — Significant intrusion (including roof)
    - >12 inches occupant site OR
    - >18 inches any site OR
    - Need for extrication for entrapped patient
  - — Death in passenger compartment
  - — Child (age 0-9 years) unrestrained or in unsecured child safety seat
  - — Vehicle telemetry data consistent with severe injury
- Rider separated from transport vehicle with significant impact (e.g., motorcycle, ATV, horse, etc.)
- Pedestrian/bicycle rider thrown, run over, or with significant impact
- Fall from height >10 feet (all ages)

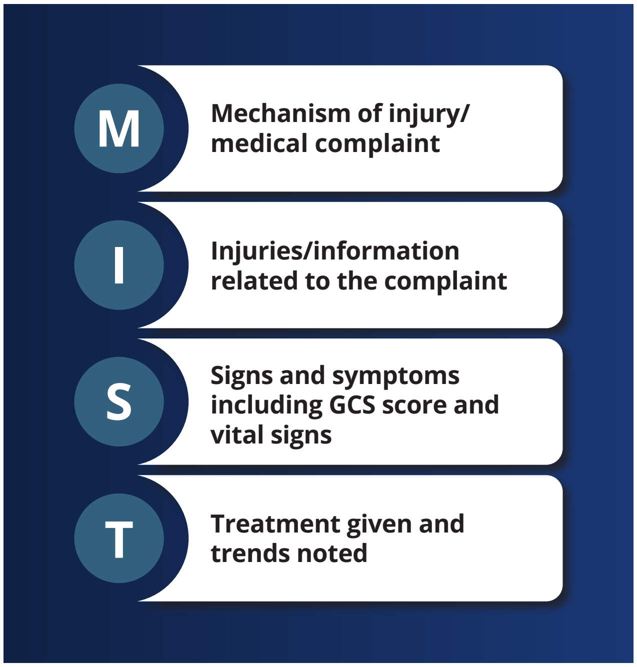
EMS Judgment

Consider risk factors, including:
- Low-level falls in young children (age ≤5 years) or older adults (age ≥65 years) with significant head impact
- Anticoagulant use
- Suspicion of child abuse
- Special, high-resource healthcare needs
- Pregnancy >20 weeks
- Burns in conjunction with trauma
- Children should be triaged preferentially to pediatric capable centers

If concerned, take to a trauma center

Patients meeting any one of the YELLOW CRITERIA WHO DO NOT MEET RED CRITERIA should be preferentially transported to a trauma center, as available within the geographic constraints of the regional trauma system (need not be the highest-level trauma center).

■ **Figure 1-3: Mechanism, Injuries, Symptoms and Signs and Treatment (MIST) Systemic Handover Tool.** The MIST tool allows for a standardized, systematic way to manage handovers from prehospital personnel to the in-hospital team. Adapted from Iedema R, Ball C, Daly B, et al. Design and trial of a new ambulance-to-emergency department handover protocol: 'IMIST-AMBO'. *BMJ Quality & Safety.* 2012;21:627-633.


M
Mechanism of injury/ medical complaint
I
Injuries/information related to the complaint
S
Signs and symptoms including GCS score and vital signs
T
Treatment given and trends noted

RESOURCE-APPROPRIATE CARE

ATLS presents one safe way to manage an injured patient. Specific types of injuries, clinician training, resources, practice environments, geographic location, and a multitude of other factors differ for an individual resuscitation. ATLS recognizes that modifications of protocols are necessary to meet these patient- and site-specific variables and provide optimal outcomes.

Facilities should know what their capabilities are before patients arrive—this includes personnel, equipment, and expertise. This is particularly important when making decisions about patient disposition. Prior arrangements with other facilities for the transfer of patients with injuries exceeding clinician and/or institutional capabilities allow efficient progress toward definitive care for patients.

Clinicians should strive to be aware of best practice recommendations regarding elements of initial trauma care while acknowledging that protocols and procedures for management must use existing resources. Issues and gaps that are identified are opportunities for advocacy, and results of team debriefing may be useful in approaching those responsible for allocation of resources.

TRIAGE AND DISASTER PREPAREDNESS

Hospitals should regularly practice preparing for multiple and mass casualty situations. Detailed information about the process of triage and disaster preparedness may be found in *Chapter 17, Triage and Disaster Management.*

■ **Figure 1-4: Transfer Communication Using the S-xABCDE-BAR Method.** A comprehensive, systematic transfer communication tool assures that all relevant information is relayed to personnel assuming care of the injured patient. Adapted from Shahid S, Thomas S. Situation, Background, Assessment, Recommendation (SBAR) communication tool for handoff in health care—A narrative review. *Saf Health*. 2018;4(7).

S-xABCDE-BAR Communication Tool

Acronym	Intent	Information
S-xABCDE	**Situation-x-Airway-Breathing-Circulation-Disability-Exposure/Environment**	• Referring clinician and facility • Name, age, gender, mechanism of injury • Indication for transfer • **x-**emergency hemorrhage control interventions (e.g. pressure, packing, or tourniquet) • **Airway:** assessment, intervention • **Breathing:** assessment, intervention • **Circulation:** assessment, intervention • **Disability**: assessment, intervention • **Environment/Exposure:** assessment, intervention
B	**Background**	• AMPLE history • Fluid/blood administered • Medications (date and time) • Images • Reduction/splints
A	**Assessment**	**Current Status:** • Physiology • Response to interventions • Likely injuries
R	**Recommendation**	• Transport mode and capability • Transport interventions • Other necessary interventions

PRIMARY SURVEY WITH SIMULTANEOUS RESUSCITATION

The initial assessment, starting with the primary survey, uses a systematic approach that identifies, prioritizes, and treats life-threatening conditions. The sequence of care, known as the xABCDE algorithm, is described in ■ **Table 1-1**.

CONTROL OF EXSANGUINATING EXTERNAL HEMORRHAGE

External hemorrhage is often associated with extremity wounds and fractures. However, soft-tissue injuries anywhere on the body may result in significant external blood loss. One frequently overlooked site of ongoing external blood loss is the scalp. The mainstays of external hemorrhage management in the hospital mirror those used in the field: direct pressure, wound packing, and application of a tourniquet where appropriate. Clinicians should become familiar with when tourniquet application is most helpful. Small soft-tissue wounds with superficial arterial bleeding may often be managed with direct pressure alone. In contrast, extremity wounds with rapid bleeding from large vessels or with multiple sites of bleeding (e.g., "mangled" extremities) can often only be controlled with application of a tourniquet. **Hemorrhage from any extremity wound that does not respond to direct pressure or wound packing should have a tourniquet applied. Early placement of tourniquets in the setting of massive extremity wound hemorrhage is associated with improved outcomes.**

Not all exsanguinating external hemorrhage can be addressed with a tourniquet. Significant blood loss from injuries to the neck, pharynx, and mouth must initially be treated with direct pressure

■ **Table 1-1: The Primary Survey and Simultaneous Resuscitation.** The xABCDE algorithm provides clinicians with a systematic approach to identifying, prioritizing, and treating life-threatening conditions. Following the sequence lessens the chance of missed injuries and encourages efficient evaluation.

The Primary Survey

& SIMULTANEOUS RESUSCITATION

		Key Causes and Issues
x	e**x**sanguinating e**x**ternal hemorrhage	Massive bleeding from open extremity and other wounds
A	**A**irway	Inability to maintain the airway patency due to direct injury, altered mental status, shock
B	**B**reathing	Compromise of oxygenation and/or ventilation due to direct injury, shock
C	**C**irculation	1. Presence of shock from hemorrhagic, neurogenic, cardiogenic, or other sources 2. Hemorrhage control 3. Restoration and maintenance of end-organ perfusion
D	**D**isability	Injury to the central nervous system • Traumatic brain injury • Spinal cord injury
E	**E**xposure/ **E**nvironment	1. Exposure to prevent missed injuries while maintaining patient dignity 2. Maneuvers to prevent hypothermia

and wound packing and often require rapid definitive control via angiography or operation. Significant bleeding from scalp wounds may be managed with direct pressure but may also require control with sutures or clips. Complex scalp wounds should be carefully monitored even after bleeding is controlled and may require more comprehensive debridement and cleansing.

Recently, "junctional tourniquets" have been recommended as a method of controlling bleeding from the groin/iliac area and the proximal axillary area. These have been tested mostly in combat situations and are not widely available in civilian centers. In the absence of such devices, junctional bleeding in the groin or axilla is managed with direct pressure.

AIRWAY MAINTENANCE WITH CERVICAL SPINE MOTION RESTRICTION

Initial evaluation of the airway in a trauma patient focuses on determination of patency. Rapid assessment for airway obstruction involves identifying foreign bodies; facial, mandibular, and/or tracheal fractures; and other injuries that may cause obstruction. The clinician should suction or clear the airway of accumulated blood, debris, and secretions. Assessment for signs of airway edema or smoke inhalation is also important in certain patients with thermal injury. **All airway maneuvers in a patient at risk for spinal injury are performed with cervical spine motion restriction.** For additional information, see *Chapter 4, Airway Assessment and Management, and Chapter 7, Disability: Neurological Assessment and Management.*

If a patient is able to phonate and communicate verbally, the airway is unlikely to be in immediate jeopardy. However, frequent reassessment of airway status is critical.

A patient with head injuries resulting in an altered level of consciousness and/or a GCS score of 8 or lower will usually require a definitive airway, which ATLS defines as an airway device in the trachea with an inflated cuff distal to the vocal cords.

Several maneuvers may be performed to maintain airway patency while other elements of the primary survey are being performed or in preparation for a definitive airway. Techniques such as the jaw thrust can lift the tongue away from the back of the throat, ameliorating upper airway obstruction and allowing for effective oxygenation and ventilation with a bag-valve mask apparatus. Devices such as the laryngeal mask airway and other supraglottic airways may be employed to temporarily maintain airway patency.

Recent literature has emphasized the importance adequate resuscitation plays in patients undergoing definitive airway placement, particularly when medications are administered for rapid-sequence intubation. In addition to volume administration, some studies have suggested vasopressor administration for temporary adjunctive management of hypotension during intubation. While vasopressor administration may be useful in these select situations, **clinicians should not use vasopressors as first-line therapy for shock or as a replacement for diagnosing and treating the cause of the shock state.**

When a definitive airway is required, the responsibility for that task varies depending on clinician experience and practice environment. Clinicians should be aware of standard procedures for their practice setting. Any airway may be considered as potentially complex or "difficult" in a trauma patient, and clinicians should prepare accordingly. Equipment for surgical airway (also known as "Equipment for incisional airway should be available, along with appropriate adjuncts") should be available, along with appropriate adjuncts (e.g., gum-elastic bougie introducer). Clinicians should be open to soliciting assistance from more experienced personnel when appropriate. *See Chapter 4, Airway Assessment and Management,* for additional information.

BREATHING AND VENTILATION

Airway patency alone does not ensure adequate ventilation. Adequate gas exchange is required to maximize oxygenation and elimination of carbon dioxide. Ventilation requires adequate function of the lungs, chest wall, and diaphragm; therefore, clinicians must rapidly examine and evaluate each component.

Injuries that significantly impair ventilation and result in immediate life threats include tension pneumothorax, massive hemothorax, open pneumothorax, pulmonary contusion, and tracheal or bronchial injuries. These injuries should be identified during the primary survey and often require immediate attention to ensure effective ventilation. Some injuries affect both breathing and circulation in the primary survey. A tension pneumothorax, for example, acutely compromises ventilation and impairs venous return to the right heart; this results in hypotension as well as respiratory distress and decreased breath sounds on the side of injury. Chest decompression in this situation is an emergency procedure needed to restore both ventilatory and circulatory function.

Every injured patient should initially receive supplemental oxygen. Oxygen may be delivered by a mask-reservoir device to achieve optimal oxygenation. A pulse oximeter is used to monitor adequacy of hemoglobin oxygen saturation. Frequent reassessment and monitoring are necessary. A simple pneumothorax, for example, can convert to a tension pneumothorax when a patient is intubated and positive pressure ventilation is applied.

Continuous end-tidal CO_2 ($ETCO_2$) monitoring, when available, can also be used for control of ventilation to avoid hypoventilation and hyperventilation when correlated with the arterial partial pressure of CO_2 ($PaCO_2$). It is important to recognize that $ETCO_2$ reflects both ventilation and perfusion; thus, low $ETCO_2$ may be an early sign of hypovolemic shock or poor cardiac output. An arterial blood gas (ABG) analysis should be obtained to ensure the $ETCO_2$ correlates with the $PaCO_2$ prior to using $ETCO_2$ to adjust ventilation. In the setting of cardiac arrest, $ETCO_2$ can be used to evaluate the quality of cardiopulmonary resuscitation (CPR) and predict return of spontaneous circulation (ROSC). See *Chapter 5, Breathing and Ventilation Assessment and Management,* for additional information.

CIRCULATION, HEMORRHAGE CONTROL, AND MANAGEMENT OF SHOCK

Among the more complex aspects of the primary survey are those associated with the diagnosis and management of shock in the injured patient. **Shock is defined as insufficient tissue perfusion and oxygenation.** The failure to diagnose and effectively manage shock in the prehospital setting and during the initial assessment can result in fatality in the acute setting; it also has implications for the patient later in their course by potentially contributing to organ failure and late mortality.

DIAGNOSIS OF SHOCK

Early signs of shock can include tachycardia, tachypnea, sequalae of compensatory vasoconstriction (shivering, decreased capillary refill), and anxiety. Most laboratory studies are not helpful in the diagnosis of shock; the exceptions are blood gases and lactate levels, which may be abnormal before other findings manifest. When compensatory mechanisms begin to fail, signs of end-organ dysfunction appear: a patient may have decreased/altered mental status, decreased urine output, and hemodynamic abnormality as manifested by narrowed pulse pressure and/or hypotension. **Clinicians should remember that low systolic blood pressure is a relatively late sign of shock; compensatory mechanisms can prevent a measurable fall in systolic pressure until up to 30% of the patient's blood volume is lost.**

Shock in trauma patients can be broadly classified as hemorrhagic or nonhemorrhagic. Nonhemorrhagic causes of shock may be further classified as obstructive causes (e.g., tension pneumothorax, cardiac tamponade), distributive causes (e.g., neurogenic, septic), and primary cardiogenic causes (e.g., blunt cardiac injury). Obstructive causes of shock such as tension pneumothorax and cardiac tamponade are addressed prior to (or simultaneously with) investigation of hemorrhage. The initial resuscitation of neurogenic and cardiogenic shock mirrors that of hemorrhagic shock; thus, sources of hemorrhage should be excluded prior to investigation of these issues. Septic and anaphylactic shock are unusual in the setting of acute injury but can be considered if the clinical findings are suggestive.

Hemorrhage remains the most common etiology of shock in the injured patient and should thus be excluded before considering other causes in most cases. As discussed earlier in this chapter, immediate attention should be given to controlling exsanguinating external bleeding. Should a patient remain in shock once external bleeding has been addressed, consideration should be given to internal, or cavitary, bleeding sources. These include the pleural cavities bilaterally, the peritoneal cavity, the retroperitoneum and pelvis, and the muscle or subcutaneous tissue. Bleeding in any of these cavities can result in enough blood loss to lead to shock (■ **Figure 1-5**).

See *Chapter 6, Circulation Assessment and Volume Resuscitation,* for information on how to diagnose and address blood loss in these areas.

The MOST effective method of restoring adequate cardiac output, end-organ perfusion, and tissue oxygenation in the setting of hemorrhage is to restore venous return to normal by locating and stopping the source of bleeding. Volume repletion will allow recovery from the shock state only when the bleeding is controlled.

RESUSCITATION STRATEGIES FOR SHOCK

As stated above, control of the source of shock is the most effective element in the treatment of shock. However, maintenance of perfusion while this is being accomplished remains a challenge for the clinician.

In the setting of hemorrhage, replacement of blood loss with blood component therapy or whole blood is preferred over the use of crystalloid. There are data documenting the disadvantages of crystalloid use in this setting, including immunologic alterations, coagulation issues, and pulmonary and cardiac complications. When large-volume hemorrhage is suspected, it is useful to have a massive transfusion (or hemorrhage) protocol (MTP or MHP) in place that can be activated expeditiously. Resuscitation endpoints vary according to mechanism and suspected injuries. In a patient with isolated penetrating trauma to the torso, clinicians might use permissive hypotension during resuscitation, aiming for a lower-than-normal systolic blood pressure that will maintain tissue perfusion but not exacerbate bleeding. Conversely, the Brain Trauma Foundation recommends age-dependent systolic blood pressure goals for patients with suspected traumatic brain injury (TBI) that are somewhat higher to prevent secondary brain injury.

Recent literature has suggested that whole blood is preferable to fractionated blood components. However, not all prehospital organizations or hospital facilities have immediate access to whole blood or even blood component products. Even in centers that are well supplied, a multiple or mass casualty event may overwhelm blood product administration capacity, and alternative resuscitation strategies will be needed. Clinicians in such situations must analyze how to use their resources to optimize outcomes.

See *Chapter 6, Circulation Assessment and Volume Resuscitation,* for additional details on resuscitation strategies for shock.

DISABILITY

A rapid neurologic evaluation establishes the patient's level of consciousness, determines pupillary size and reaction, identifies the presence of lateralizing signs, and determines if there is gross motor evidence of a spinal cord injury.

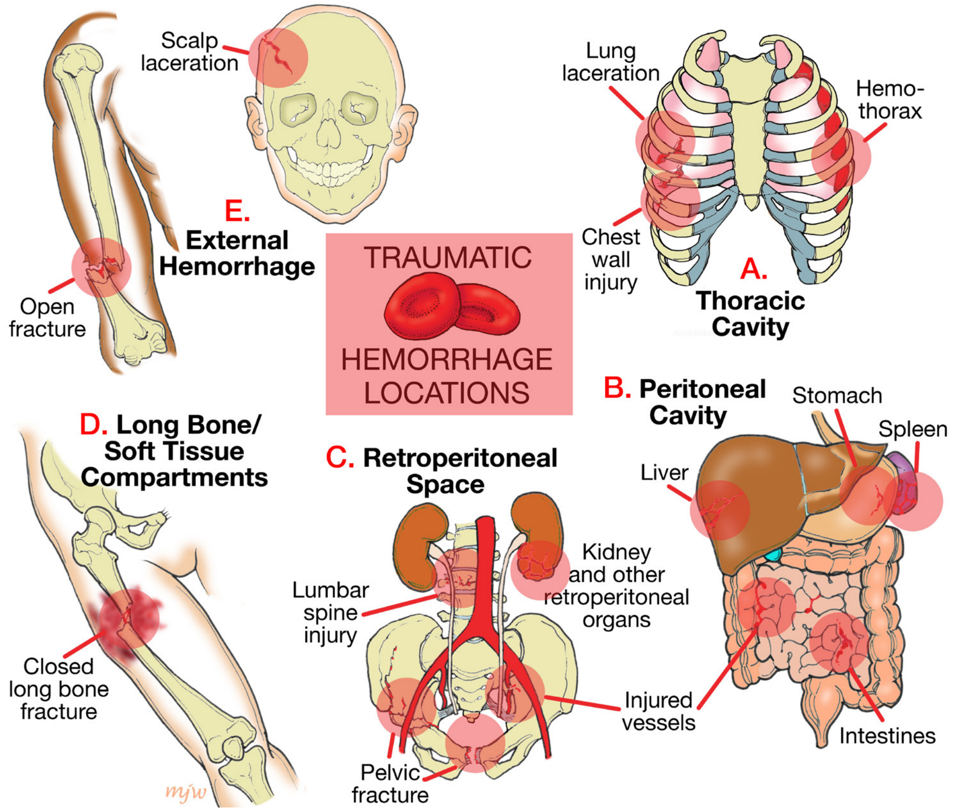
The GCS is a quick, simple, and objective method of determining level of consciousness. The motor score of the GCS correlates with outcome. A decrease in level of consciousness may indicate progression of direct cerebral injury or decreased cerebral oxygenation and/or perfusion due to a shock state. Although hypoglycemia, alcohol, narcotics, and other drugs can alter a patient's level of consciousness, clinicians should assume that changes in level of consciousness are due to traumatic injury until proven otherwise.

Primary brain injury results from the structural effect of an injury to the brain. Prevention of secondary brain injury—by maintaining adequate oxygenation and perfusion—is the main goal of management during the primary survey. Because evidence of brain injury can be absent or minimal at the time of initial evaluation, frequent reexamination is critical. Patients with evidence of brain injury or spinal cord injury should be treated at a facility that has the personnel and resources to anticipate and manage the needs of these patients. When resources to care for these patients are not available, arrangements for transfer should begin as soon as this condition is recognized. Optimally, neurosurgical, spine, or other appropriate specialty consultation should be obtained once brain or spinal cord injuries are identified.

In a hemodynamically abnormal patient with clinical findings of a spinal cord injury, the clinician should still exclude hemorrhagic shock before assuming hypotension is due only to the spinal cord injury. Patients may have both hemorrhagic and neurogenic shock present, depending on the mechanism.

See *Chapter 7, Disability: Neurological Assessment and Management,* for additional information.

■ Figure 1-5: Potential Anatomic Locations for Blood Loss, "One on the Floor and Four More" or "Four and the Floor". **A.** Thoracic cavity. **B.** Peritoneal cavity. **C.** Pelvic and Retroperitoneal Space. **D.** Long bone fracture sites, muscle compartments, and subcutaneous tissue. **E.** External hemorrhage ("the floor").


Scalp laceration
E. External Hemorrhage
Open fracture
TRAUMATIC HEMORRHAGE LOCATIONS
Lung laceration
Hemo-thorax
Chest wall injury
A. Thoracic Cavity
B. Peritoneal Cavity
Stomach
Spleen
Liver
D. Long Bone/ Soft Tissue Compartments
C. Retroperitoneal Space
Kidney and other retroperitoneal organs
Lumbar spine injury
Closed long bone fracture
Injured vessels
Intestines
Pelvic fracture
mjw

EXPOSURE AND ENVIRONMENTAL CONTROL

All patients who present with injury should be examined carefully to prevent missing an injury. This requires that all clothing and jewelry be removed. Maintaining patient dignity and modesty is a priority during this process. Patient belongings are collected and secured per institution policy.

Hypothermia will aggravate shock and coagulopathy. Therefore, warmed blankets, convection warming systems, elevated room temperature, and warmed resuscitative fluids are of critical importance. Information about recognition and treatment of systemic hypothermia can be found in *Chapter 8, Exposure and Environmental Threats in the Primary Survey.*

ADJUNCTS TO THE PRIMARY SURVEY WITH RESUSCITATION

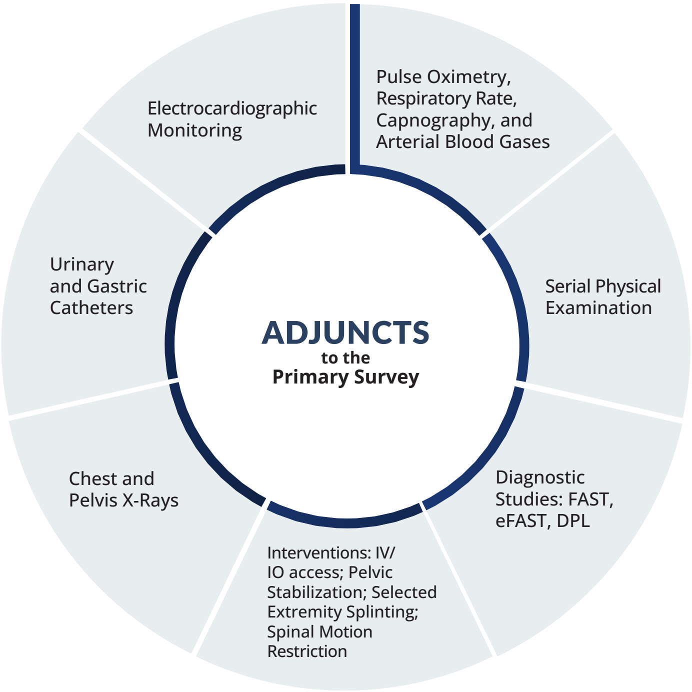
Adjuncts employed during the primary survey can be used to monitor, diagnose, treat, and prevent harm. Continuous electrocardiography (ECG), pulse oximetry, and capnography can allow the clinician to monitor real-time changes in a patient's status. Diagnostic studies such as chest and pelvis x-rays, focused assessment with sonography for trauma (FAST) and extended FAST (eFAST), and diagnostic peritoneal lavage (DPL) provide the clinician with information about life-threatening injuries that should be diagnosed during the primary survey. Urinary and gastric catheters can provide diagnostic information (e.g., the presence of blood) and monitoring information (hourly urine output) and can be therapeutic as well (decompression of the urinary bladder and stomach). Interventions such as spinal motion restriction, extremity splinting, and pelvic stabilization (in the setting of suspected or confirmed pelvic fracture) can provide preventive and therapeutic benefits for the trauma patient. Serial physical examination can alert clinicians to significant changes in patient status (**■ Figure 1-6**).

Some novice trauma clinicians can become confused about when certain adjuncts are utilized and whether they are part of the primary or the secondary survey. **As a general rule, if a monitoring device, diagnostic test, or procedure assists the clinician in managing immediate life threats, it can be included as part of the primary survey.** For example, in a hemodynamically abnormal patient with suspected abdominal trauma, it is appropriate to use FAST or DPL as part of the primary survey. Similarly, splinting a femur fracture or stabilizing the pelvis to mitigate blood loss that may be causing a shock state can also be considered primary survey procedures.

MONITORING

Physiologic parameters such as pulse rate, blood pressure, pulse pressure, ventilatory rate, pulse oximetry, capnography, and body temperature are measurable assessments that can reflect the adequacy of resuscitation. Values for these parameters should be obtained as soon as is practical and should be evaluated at regular intervals.

■ **Figure 1-6: Adjuncts to the Primary Survey with Resuscitation.** Any monitoring tool, diagnostic test, intervention, or procedure that can assist the clinician in the diagnosis and management of immediate life-threatening conditions is appropriate to use as part of the Primary Survey. Note the importance of serial physical examination as part of the re-evaluation process in many trauma patients.


ADJUNCTS
to the
Primary Survey
Pulse Oximetry, Respiratory Rate, Capnography, and Arterial Blood Gases
Serial Physical Examination
Diagnostic Studies: FAST, eFAST, DPL
Interventions: IV/IO access; Pelvic Stabilization; Selected Extremity Splinting; Spinal Motion Restriction
Chest and Pelvis X-Rays
Urinary and Gastric Catheters
Electrocardiographic Monitoring

ELECTROCARDIOGRAPHIC MONITORING

ECG monitoring of all trauma patients is important. Dysrhythmias—including unexplained tachycardia, atrial fibrillation, premature ventricular contractions, and ST segment changes—can indicate blunt cardiac injury. Pulseless electrical activity can indicate cardiac tamponade, tension pneumothorax, or profound hypovolemia. When bradycardia, aberrant conduction, and premature beats are present, hypoxia and hypoperfusion should be suspected immediately. Extreme hypothermia also produces dysrhythmias.

PULSE OXIMETRY

Pulse oximetry is a valuable adjunct for monitoring oxygenation in injured patients. A small sensor is placed on the finger, toe, earlobe, or another convenient place. Most devices display pulse rate and oxygen saturation continuously. The relative absorption of light by oxyhemoglobin and deoxyhemoglobin is assessed by measuring the amount of red and infrared light emerging from tissues traversed by light rays and processed by the device, producing an oxygen saturation level. Pulse oximetry does not measure the partial pressure of oxygen or carbon dioxide. Note that pulse oximetry can be inaccurate in patients exposed to carbon monoxide. Quantitative measurement of these parameters occurs as soon as is practical and is repeated periodically to establish trends.

Hemoglobin saturation from the pulse oximeter should be compared with the value obtained from ABG analysis. Inconsistency indicates that one of the two determinations is in error.

VENTILATORY RATE, CAPNOGRAPHY, AND ARTERIAL BLOOD GASES

Ventilation can be monitored using $ETCO_2$ levels. $ETCO_2$ can be detected using colorimetry, capnometry, or capnography—a noninvasive monitoring technique that provides insight into the patient's ventilation, circulation, and metabolism. Because endotracheal tubes can be dislodged whenever a patient is moved, capnography can be used to confirm intubation of the airway (versus the esophagus) but does not confirm the precise position of the endotracheal tube within the airway. Continuous $ETCO_2$ monitoring, when available, can also be used for control of ventilation to avoid hypoventilation and hyperventilation. As mentioned previously, it may be used as an early indicator of hypovolemic shock and poor cardiac output, as well as to predict return of spontaneous circulation (ROSC) during CPR.

ABG is a particularly versatile test that can be obtained in the trauma bay. It provides specific information about oxygenation (PaO_2 and O_2 saturation) as well as ventilation ($PaCO_2$). It also provides information about the patient's acid-base status (pH and base excess/deficit); this can alert the clinician to the presence of shock before other measurements (like blood pressure) become indicative. Trends in pH and base excess levels can also reflect the progress of resuscitation. Lactate levels can also be obtained and trended to accomplish the same goal. Depending on the practice setting, ABG may be used in place of technological devices to monitor oxygenation, ventilation, and acid-base status.

OTHER INTERVENTIONS IN THE PRIMARY SURVEY

Some interventions are performed during the primary survey to protect the patient from potential harm or to treat life-threatening injuries.

INTRAVENOUS/INTRAOSSEOUS ACCESS

Even if a patient does not require immediate volume resuscitation, it is important in most cases to obtain intravenous or intraosseous access. Having access will allow for the rapid administration of medications or fluids should the patient's status change. Short-length, large-caliber intravenous catheters remain the ideal for resuscitation of trauma patients. Intraosseous access is commonly obtained via the humeral or tibial route.

SPINAL MOTION RESTRICTION

In any patient at risk for spinal cord injury, spinal motion restriction measures should be applied. This usually includes placement of a cervical collar or similar device and maintaining logroll precautions when the patient is moved or turned. Maintaining cervical motion restriction is an important component of the intubation process in at-risk patients. Patients should not be left on long spine boards for extended periods, as they do not inherently provide immobilization of the spine and patients left on them can sustain significant pressure injuries.

PELVIC STABILIZATION

In hemodynamically abnormal patients with suspected pelvic fractures, stabilization of the pelvic girdle with a sheet or commercial device should be performed during the primary survey. See *Chapter 6, Circulation Assessment and Volume Resuscitation; Chapter 10, Musculoskeletal Trauma; and Chapter 21, Thoracic, Abdominopelvic, and Genitourinary Trauma,* for additional details.

EXTREMITY SPLINTING

Although extremity splinting is usually part of the secondary survey, there are situations in which it is appropriate to perform during the primary survey. Femur fractures can cause significant blood loss that may be mitigated with appropriate splinting.

X-RAY EXAMINATIONS AND OTHER DIAGNOSTIC STUDIES

PLAIN X-RAYS

Use x-ray examination judiciously, and do not delay patient resuscitation or transfer to definitive care in patients who require a higher level of care. Anteroposterior (AP) chest and AP pelvic x-rays often provide information to guide resuscitation efforts of patients with blunt trauma and can also be helpful to locate retained missiles in penetrating trauma. Chest x-rays can show potentially life-threatening injuries that require treatment or further investigation and can document placement of devices such as endotracheal and chest tubes. Pelvic x-rays can show fractures of the pelvis that may indicate the need for early blood transfusion. These studies can be obtained in the resuscitation area with a portable/bedside x-ray unit, but not when doing so will interrupt the resuscitation. Do obtain essential diagnostic x-rays, even in pregnant patients.

FAST, eFAST, AND DPL

In the setting of suspected abdominal trauma, FAST and DPL are adjuncts that can be used to detect peritoneal blood as part of the primary survey. Many sites employ FAST, as it is noninvasive, but DPL is still used in sites that have a large burden of penetrating trauma or less access to ultrasound technology. Both can be challenging to perform in obese patients and pregnant patients. While the indications for its use do not vary, DPL technique must be altered in patients who are pregnant, obese, or have had prior laparotomies. Obesity and intraluminal bowel gas can interfere with images obtained on FAST. In a hemodynamically abnormal patient, the presence of intraperitoneal blood with either FAST or DPL indicates the need for surgical intervention. In hemodynamically normal patients, a surgeon should still be consulted to direct care when blood is detected. Note that neither of these studies can effectively evaluate the retroperitoneum. The eFAST procedure can be used to detect pneumothoraces and hemothoraces. Success when performing any of these procedures depends on the clinician's experience and level of skill.

In the absence of the recommended technology, a clinician should rely on patient presentation and a high level of suspicion to avoid missing injuries. For example, diagnosis of a tension pneumothorax is primarily clinical. Similarly, if a polytrauma patient in shock has no evidence of external hemorrhage, has a clear chest exam/x-ray, and has no evidence of pelvic or femur fractures, intra-abdominal bleeding must be a primary consideration as the source of shock, even if it cannot be specifically diagnosed.

URINARY AND GASTRIC CATHETERS

The placement of urinary and gastric catheters may occur during or following the primary survey.

URINARY CATHETERS

Urinary output is a sensitive indicator of a patient's volume status and reflects renal perfusion. Monitoring of urinary output is best accomplished by insertion of an indwelling bladder catheter. In addition, a urine specimen should be submitted for routine laboratory analysis. Transurethral bladder catheterization is contraindicated for patients who have suspected urethral injury. **Suspect a urethral injury in the presence of either blood at the urethral meatus or perineal ecchymosis on exam of the genitalia and perineum. If a urethral injury is suspected, placement of a transurethral catheter must be delayed** until a retrograde urethrogram is performed to rule out injury.

At times, anatomic abnormalities (e.g., urethral stricture or prostatic hypertrophy) preclude placement of indwelling bladder catheters, even with appropriate technique. Nonspecialists should avoid excessive manipulation of the urethra and use of specialized instrumentation. Consult a urologist early in such situations.

GASTRIC CATHETERS

A gastric catheter is indicated to decompress stomach distention, decrease the risk of aspiration, and check for upper gastrointestinal hemorrhage from trauma. It is considered an important adjunct to employ following endotracheal intubation. Decompression of the stomach may reduce the risk of aspiration but does not prevent it entirely. Thick and semisolid gastric contents will not return through the tube, and placing the tube itself can induce vomiting. The tube is effective only if it is properly positioned and attached to appropriate suction.

Blood in the gastric aspirate may indicate oropharyngeal (i.e., swallowed) blood, traumatic insertion, or injury to the upper digestive tract. **If a fracture of the cribriform plate is known or suspected, insert the gastric tube orally to prevent intracranial passage. In this situation, any nasopharyngeal instrumentation is potentially dangerous, and an oral route is recommended.**

SERIAL PHYSICAL EXAMINATION

With the availability of technology, it can become easy to neglect the value of physical examination. Serial physical examination can be critical to ensuring that changes in patient status (and by extension, evolving injuries) are not missed. Examples include repeating GCS assessments, reassessing the girth of an injured extremity, examining for expansion of a soft-tissue hematoma, reevaluating pulses, and repeating exams in patients with abdominal trauma. Changes in the acuity or character of pain after injury may signal worsening of a physiologic process.

SECONDARY SURVEY IN THE INITIAL ASSESSMENT

In a trauma patient, the secondary survey begins after the primary survey is completed (in hemodynamically normal patients) or after the patient is responding to resuscitation (in hemodynamically abnormal patients).

For some patients, a complete secondary survey cannot be accomplished before the patient must be transferred to definitive care, be it an operating room or another hospital facility. However, clinicians should make every effort to obtain secondary survey information when possible.

As with the primary survey, frequent reassessment is critical during the secondary survey. Any deterioration in patient status should prompt repeating the primary survey.

For additional information, see *Chapter 14, Initial Assessment: Secondary Survey.*

REEVALUATION

Trauma patients must be reevaluated frequently to ensure that new findings are not overlooked and to discover any deterioration in previously noted findings. As initial life-threatening injuries are managed, other equally life-threatening problems or less severe injuries may become apparent, which can significantly affect the ultimate prognosis of the patient. A high index of suspicion facilitates early diagnosis and management. As noted in "Adjuncts to the Primary Survey with Resuscitation" section, serial physical examination must be employed in addition to frequent technological monitoring. The team leader should ensure that all team members feel comfortable in communicating any changes in patient status to the entire group.

DEFINITIVE CARE

Whenever the patient's treatment needs exceed the capability of the initial treating clinician or institution, transfer is considered. This decision requires a detailed assessment of the patient's injuries and knowledge of the institution's capabilities, including equipment, resources, and personnel.

Interhospital transfer guidelines will help determine which patients require the highest level of trauma care; see ACS COT's *Resources for Optimal Care of the Injured Patient (2022 Standards).* These guidelines take into account the patient's physiologic status, diagnosed anatomic injury, mechanisms of injury, concurrent diseases, and other factors that can alter the patient's prognosis. Emergency department and surgical personnel may use these guidelines to determine whether the patient requires transfer to a trauma center or the closest appropriate hospital capable of providing more specialized care. The closest appropriate facility is chosen based on its overall capabilities to care for the injured patient.

Communication between those who provide initial care for the patient and those who will provide definitive care is critical to optimal patient safety and outcomes. This communication is not only useful for interfacility transfers but may be used even if definitive care takes place in the same institution that provided emergency care. The S-xABCDE-BAR acronym is a useful method for structuring this communication (see ■ **Figure 1-4**).

The other important communication element in this process is that which occurs between the healthcare team and the patient/family. Particularly when a patient is being transferred to another facility, the family may need additional information and support beyond the medical data.

See Chapter 15, Transfer to Definitive Care, for more information.

SPECIAL POPULATIONS

More detailed information on these topics can be found in *Chapter 11, Trauma in the Pediatric Patient; Chapter 12, Trauma in the Older Adult;* and *Chapter 13, Trauma in the Pregnant Patient.*

Injury presentation in pediatric, older adult, and pregnant populations, as well as in obese patients, athletes, and other populations, may include some distinct characteristics. The following sections discuss some initial assessment considerations specific to these populations; however, **the priorities for the care of these patients are the same as for all trauma patients.**

TRAUMA IN PEDIATRIC PATIENTS

Pediatric patients have distinct physiology and anatomy. The dose requirements for blood, fluids, and medications vary with the size of the child. Children typically have abundant physiologic reserve and often have few signs of hypovolemia, even after severe volume depletion. When deterioration does occur, it can be precipitous and catastrophic. A child's increased metabolic rate, thin skin, and lack of substantial subcutaneous tissue also contribute to increased evaporative heat loss and caloric expenditure. Hypothermia can significantly compromise a child's response to treatment, prolong coagulation times, and adversely affect central nervous system function.

TRAUMA IN PREGNANCY

The anatomic and physiologic changes of pregnancy affect how the pregnant patient responds to injury. Pregnant patients can lose more volume/blood before they develop hypotension. As the pregnancy progresses, uterine compression of the inferior vena cava can decrease venous return; lateral uterine displacement/tilting can be an important maneuver to perform during the primary survey to restore hemodynamic normality. It is important to keep in mind that even relatively minor injury mechanisms may result in poor outcomes for the mother and the fetus, and careful monitoring is key.

TRAUMA IN OLDER ADULTS

Older adults may have a limited ability to adapt and maintain homeostasis when subjected to traumatic injury. This can be influenced by the aging process itself, medication use, and frailty. Anatomic and physiological changes associated with aging can present the clinician with challenges in managing all aspects of the xABCDE algorithm. Airway anatomy can be affected by arthritis and degenerative changes; pulmonary compliance and reserve may be diminished; and patients with essential hypertension may require a higher mean pressure to maintain perfusion, meaning "normal" blood pressure is inadequate. Susceptibility to TBI may be enhanced by the presence of cerebral atrophy and the use of anticoagulant medications, and even low-energy falls may result in spinal cord and other injuries. Finally, loss of subcutaneous fat, nutritional deficiency, and other issues may increase the risk of hypothermia.

TRAUMA IN OBESE PATIENTS

The anatomy of obese patients may make procedures such as intubation challenging. Diagnostic tests such as FAST, DPL, and CT may also be more difficult. Many obese patients have cardiopulmonary conditions, which limit their ability to compensate for injury and stress. Volume resuscitation should be based on ideal body weight and take into consideration that rapid fluid administration may exacerbate underlying comorbidities.

TRAUMA IN ATHLETES

The enhanced conditioning of athletes may mean that they will not manifest early signs of shock, such as tachycardia and tachypnea. Their resting blood pressure may be lower than expected.

COMMUNICATING SERIOUS NEWS IN THE ACUTE TRAUMA SETTING

Just as having an organized, systematic approach to the medical management of a critically injured patient is critical, communicating serious news to a patient or family should also consist of preparation and a well-formulated process. Misunderstandings and subsequent mistrust can often be avoided by taking a few minutes to create a clear, understandable message (that everyone on the healthcare team is aware of and agrees on) and communicating that message in a professional, compassionate, and empathetic manner. One approach to this process is outlined in ■ **Figure 1-7**.

Having clinicians with expertise in patient and family support, such as social workers and spiritual care professionals, can greatly assist with the process. Determine if an interpreter (professionally trained, not a family member or friend) is necessary. **It is also important to consider local cultural, religious, and other traditions when engaged in these often sensitive and disquieting conversations. Different cultures may have specific expectations about how and to whom such information is conveyed.** Cultural sensitivity and preparation by the individual clinician and the team are key.

For additional information, see *Chapter 20, Communicating Serious News in the Acute Trauma Setting.*

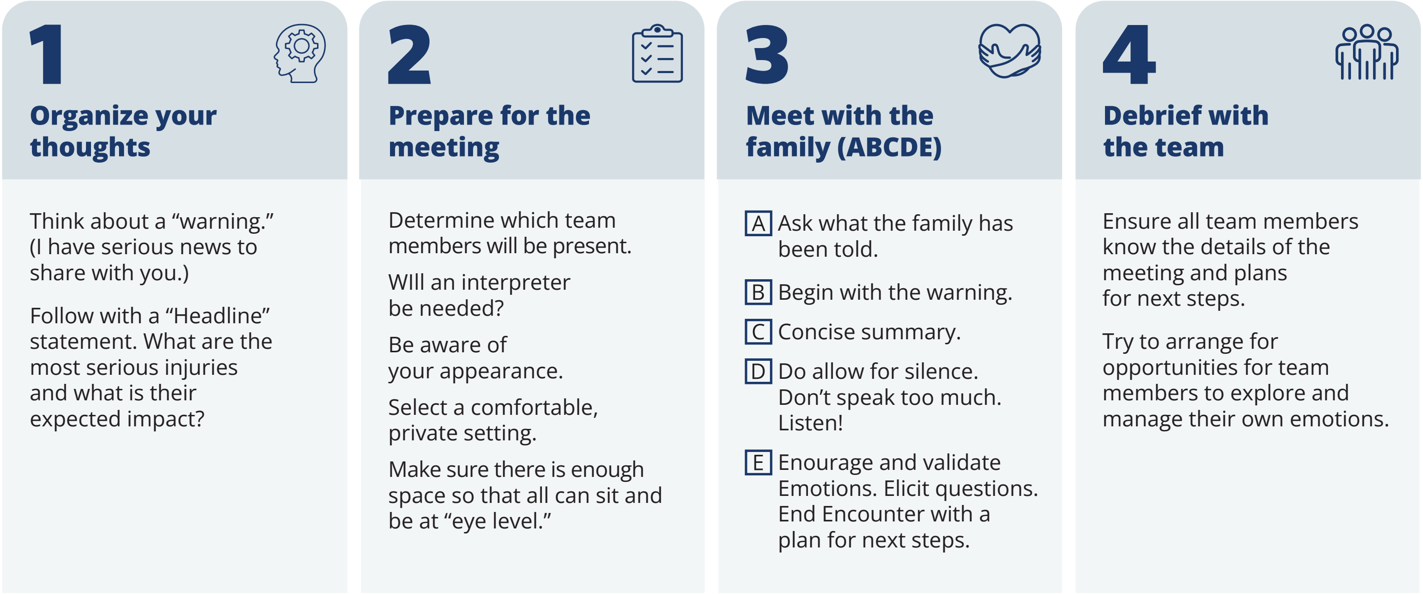
INJURY PREVENTION AND INTERVENTION

The trauma community recognizes that most traumatic incidents are not “accidents” and are subject to principles of injury prevention and intervention. There are many approaches to injury prevention; ATLS recommends that clinicians consider the “3 Es”:

- Education: What opportunities for individual, family, community, or societal education may have an impact on reducing injury?
- Engineering/Environment: How could altering the physical environment (e.g., road intersection structure) or engineering (e.g., seatbelts and airbags in vehicles) reduce injury?
- Enforcement: How could changes in legislation or policy reduce injury?

While it may not seem clear why this concept should be included in the initial assessment, it is often during this time that the most indelible impressions are made on clinicians regarding

■ **Figure 1-7: Communicating Serious News in the Acute Trauma Setting.** It is a necessary part of the work of trauma clinicians to communicate serious news to patients and families. The approach must be deliberate, with time taken to consider what should be said, who should be involved in the communication, and where and how the communication should take place. Finally, a debrief with the team assures that everyone is informed and knows the treatment plan.



1

Organize your thoughts

Think about a “warning.” (I have serious news to share with you.)

Follow with a “Headline” statement. What are the most serious injuries and what is their expected impact?

2

Prepare for the meeting

Determine which team members will be present.

WIll an interpreter be needed?

Be aware of your appearance.

Select a comfortable, private setting.

Make sure there is enough space so that all can sit and be at “eye level.”

3

Meet with the family (ABCDE)

A Ask what the family has been told.

B Begin with the warning.

C Concise summary.

D Do allow for silence. Don’t speak too much. Listen!

E Enourage and validate Emotions. Elicit questions. End Encounter with a plan for next steps.

4

Debrief with the team

Ensure all team members know the details of the meeting and plans for next steps.

Try to arrange for opportunities for team members to explore and manage their own emotions.

the nature of an injury. Spending even a few minutes to take note of injuries at your institution that occur repeatedly can lead to opportunities for education and advocacy. Similarly, opportunities to provide screening and referral for abuse or neglect, substance misuse, PTSD, and other mental health and social health concerns may become evident during the initial assessment, particularly during the secondary survey. **Even if actual action on these issues takes place at a later time, clinicians should include injury prevention principles as part of their approach to the initial care of injured patients and make sure that their concerns are included in communications with definitive care clinicians and in the medical record.**

For additional information, see *Chapter 18, Injury Prevention.*

RECORDS AND LEGAL CONSIDERATIONS

Preparing and maintaining detailed and meticulous records is crucial to the process of caring for the critically injured patient. Detailed records help promote continuity of care and allow clinicians engaged in the next phases (or future phases) of care to better understand what was done during the initial assessment and primary survey. This process can be facilitated by designating a team member as a scribe or recorder, if resources permit.

Whenever possible, consent for treatment should be obtained from either the patient or their surrogate. If consent cannot be obtained due to the emergent nature of the treatment, make every effort to explain the indications and nature of the treatment to the patient/family afterward.

If the patient is being transferred, all relevant documentation should travel with them; this includes any test results and relevant clinician notes. If possible, diagnostic studies should be placed on digital storage or other media and sent with the patient; the patient/family may also request copies of these studies. Documents such as advanced directives and living wills should also be included. The team should ensure that the family has the appropriate contact information if they have questions after the patient is transferred.

In the US, the Health Insurance Portability and Accountability Act (HIPAA) features several regulations that organizations and individuals must follow to ensure compliance. The purpose of these rules is to safeguard protected health information and privacy. In the trauma setting, clinicians are often asked to share information with associates of the patient, relying on others to be truthful in their description of their relationship to the patient. **When possible, the patient should be asked what information they want shared and with whom.** If the patient is not able to make such decisions, US-based clinicians should be familiar with the Department of Health and Human Services guidelines for Disclosures to Family and Friends and use their best judgment to act on the patient's behalf.

Although these guidelines are specific to the US, many countries and supranational entities have similar guidelines: the General Data Protection Regulation (GDPR) in the European Union; the Lei Geral de Proteção de Dados Pessoais (LGPD) in Brazil; and the Privacy Act in Australia. Similar personal data/protection guidelines are used in Malaysia, Singapore, South Korea, and Vietnam, among other countries. Protected personal health information is a concept as much as a policy, and clinicians should look to local protocols for its application.

If criminal activity is suspected in conjunction with a patient's injury, the personnel caring for the patient must preserve the evidence. All items, such as clothing and bullets, may need to be saved for law enforcement personnel. In such cases, it is important to explain to the patient/family why the patient's belongings may not be accessible to them. Laboratory determinations of blood alcohol concentrations and presence of other drugs may be required, depending on local protocols.

CHAPTER SUMMARY

The initial assessment and primary survey should follow a standardized sequence that includes the following:

- Triage (if applicable)
- Team preparation and assessment of hospital resources
- Identifying, prioritizing, and addressing life-threatening injuries using the xABCDE algorithm
- Initiating appropriate resuscitation
- Using appropriate primary survey adjuncts
- Frequent reevaluation of patient status
- Secondary survey with adjuncts
- Consideration of the need for transfer to definitive care

The priorities for treatment of critically injured patients are the same, even when they possess special characteristics (e.g., pediatric, older adult, pregnant patients). Using a standardized approach lessens the chance that a clinician will allow bias to interfere with the treatment process.

When a patient's condition changes, clinicians should repeat the primary survey and address any new findings.

Any patient with treatment needs that exceed the clinician's or institution's capabilities should be considered for transfer. Having prearranged transfer agreements facilitates this process and using a standard communication transfer tool can ensure that an effective handoff is achieved.

The initial assessment should be accomplished using effective team dynamics principles and communication. While the trauma setting can be chaotic, clinicians should ensure that the patient is treated with dignity and respect, recognizing that they may have had prior trauma (physical, emotional, social, psychological, or spiritual) in their lives, which may affect their interactions with the healthcare team.

Clinicians in the trauma setting should anticipate having to communicate serious, life-altering news to a patient and/or family and should spend time in preparation to make sure that the discussion is most beneficial for them.

Clinicians caring for trauma patients are in a unique position to recognize and catalog injury patterns and advocate for changes that may lead to more effective prevention of these injuries.

KEY LEARNING POINTS

- **The Primary Survey in the Initial Assessment requires the clinician to identify, prioritize, and address immediate life threats; it is not necessary to have a definitive diagnosis to begin urgent treatment. Using the xABCDE algorithm allows both novice and expert trauma clinicians to organize their approach to the Primary Survey, and this sequence can be applied to all trauma patients.**
- **Application of the Primary Survey requires efficient team functioning and clear, respectful communication, including among team members and between the team and other clinicians, patients, and families.**
- **Clinicians should make use of appropriate adjuncts to optimize completion of the Primary Survey depending on what resources are available to them.**
- **Frequent reevaluation is critical to the performance of the Primary Survey; a trauma patient's status may change quickly.**
- **The Secondary Survey should begin when the Primary Survey is completed and vital functions are returning to normal; in some cases, a complete Secondary Survey cannot be completed in the initial evaluation.**
- **Determining what definitive care the patient requires is also crucial; clinicians should decide as early as possible if all care can be delivered at the emergency treating facility or if the patient requires transfer.**
- **All patients should be treated with dignity—with consideration for preserving patient modesty and privacy, respecting cultural heritage, and recognizing that many patients have experienced prior trauma.**
- **Clinicians should remember their role in Injury Prevention, even in the acute setting. Recognizing injury patterns and patient risk factors can begin in the emergency department.**

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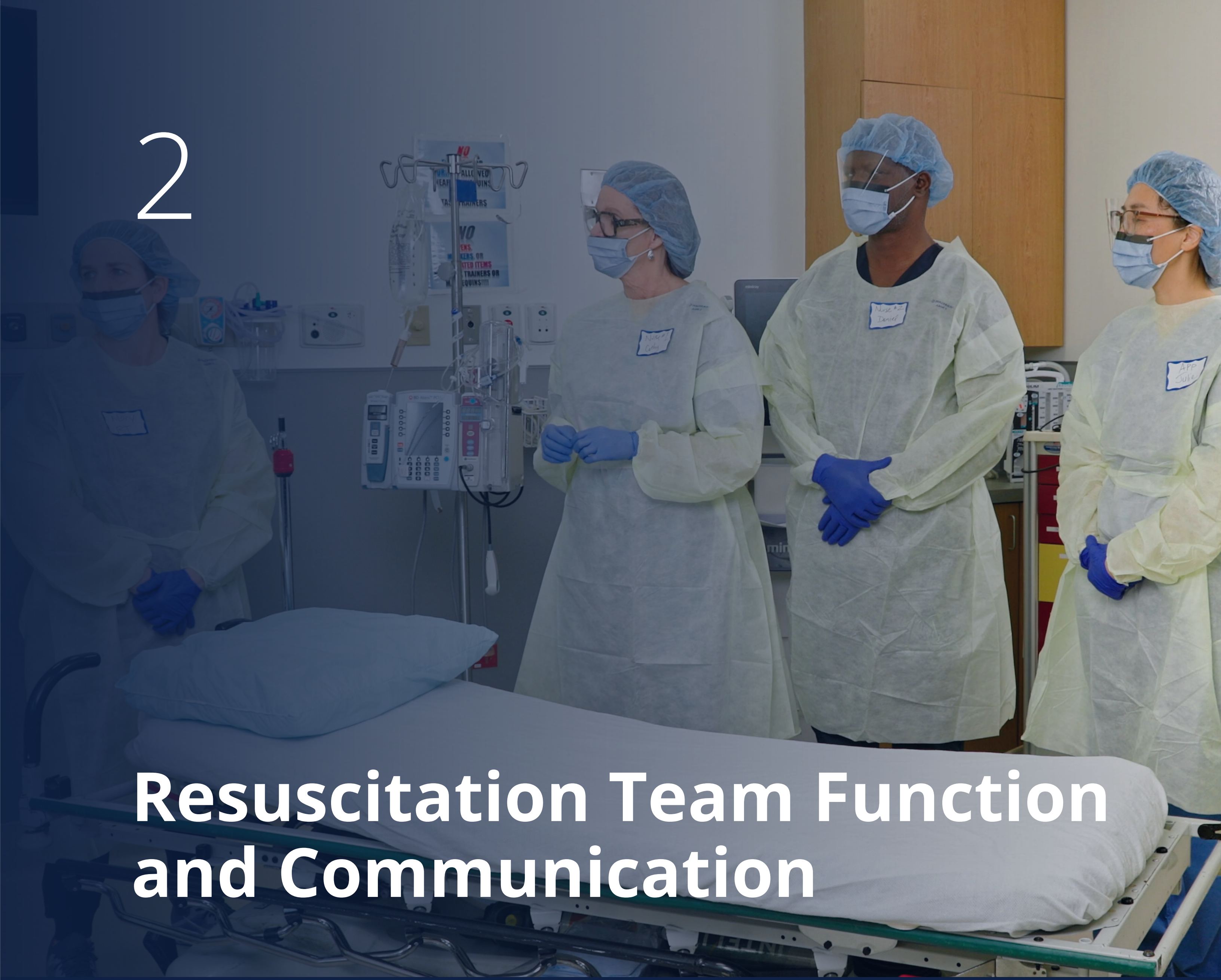


2

Resuscitation Team Function and Communication

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Explore the science of team dynamics
2. Learn behaviors of high-performing, ad hoc teams
3. Acquire tools and strategies that can be rapidly deployed in this complex environment

2

Resuscitation Team Function and Communication

CHAPTER STATEMENT

Trauma resuscitation is one of the most challenging processes in healthcare and requires team situation awareness and exceptional communication to prevent adverse events. Nontechnical skills must be embraced and trained to create exceptional teams and improved outcomes. This chapter promotes effective behaviors and provides strategies and tools to build enduring high-functioning ad hoc teams.

Despite immense advances in trauma resuscitation, as many as 29,000 patients needlessly die each year. The fast-paced, complex, and information-rich trauma environment, where teams are typically comprised of ad hoc members, is a setup for cognitive overload, impaired situational awareness, and communication failure. The initial resuscitation phase has been identified as the stage in which most preventable adverse events in trauma care occur. To change the status quo and improve patient safety, it is imperative that we create environments in which it is easy to do the right thing. **To improve outcomes, we must embrace nontechnical skills that boost effective communication,** lessen cognitive overload, promote situational awareness, and foster shared mental models to create enduring, exceptional trauma resuscitation teams.

INTRODUCTION

Trauma resuscitation is one of the most challenging processes in healthcare. There is an abundance of scientific and technical research to optimize care, but only recently have nontechnical skills been emphasized within training programs. There is an extensive body of literature around nonmedical crisis resource management (CRM) and a growing body of exceptional monographs specific to medicine and trauma. Building exceptional trauma teams of all sizes and compositions begins with an understanding of these principles. While there are many factors that shape effective teamwork across domains, **there are five key concepts that deserve special attention within the area of trauma teamwork:**

1. Leadership and followership
2. Attention and awareness
3. Verbal communication
4. Decision-making
5. Task management and coordination

To optimize care, it is crucial to educate resuscitation team members (regardless of team size) on these essential trauma teamwork skills and to have these topics included as core training principles *across disciplines*. It is important that all members of the trauma resuscitation team (e.g., physicians, nurses, respiratory therapists, medical assistants, radiology technicians, laboratory and blood bank participants) are included in such training programs, as a working knowledge of CRM principles serves to optimize team dynamics and ultimately improve patient outcomes.

KEY CONCEPTS

LEADERSHIP AND FOLLOWERSHIP

Both leaders and followers are needed to care for patients, and effective interaction between these roles is required for high-functioning teams. Resuscitation is a complex endeavor that relies on a myriad of inputs from multiple sources. As noted in Team Strategies and Tools to Enhance Performance and Patient Safety (TeamSTEPPS), effective leadership is required to direct team actions.

Being a successful leader is a learned skill; however, little formal instruction in leadership occurs during medical training, and attitudes regarding these topics are likely established early in training. To have a team, there must be followers with complementary skills. There are times when the roles of leader and follower are fluid, and high-functioning teams enable members to move seamlessly between these roles. Effective leaders promote a shared vision and collective ownership to coproduce better outcomes. These team skills must be regularly practiced and modeled. Evidence suggests that leadership skills can be honed as part of a broader teamwork training initiative. While the topic of leadership is quite popular, less attention is given to the important role of followership. Great followers, like great leaders, take ownership of team decisions, which promotes team effectiveness.

ATTENTION AND AWARENESS

Trauma resuscitation requires both focused attention and the ability to scan and receive numerous and disparate data. Focused attention comes with a risk of fixation, while scanning risks cognitive overload. This is summarized in **■ Table 2-1**. Trauma events are information-rich, subject to abrupt changes, and nonlinear. Within such dynamic events, situational awareness—an individual's ability to maintain sight of the "big picture"—is critical. Additionally, while not all data are relevant, they must still be processed.

Taking a structured approach to information processing, such as that offered by ATLS®, improves the ability of team members to determine what is immediately relevant versus what can be reserved for later investigation. A leadership style that promotes open communication should be encouraged and taught, and defined communication strategies between members (leaders and followers) are key to this endeavor. Strategies may include time outs; Situation, Background, Assessment, and Recommendation (SBAR) reassessment; probing for additional perspectives; and allowing team members to safely challenge assumptions. Promoting collective situational awareness is a skill that can be developed with education and practice and should be part of training and simulation.

Table 2-1: The Three Levels of Situational Awareness.

Level	Benefits	Risks
I - Perception		
Scanning Attention	• Sample many stimuli • Avoid fixing on one stimulus	• Stimulus overload • Lack of prioritization
Focused Attention	• Prioritize • Eliminate ‘unimportant’ cues	• Fixation error • Miss ‘important’ cues
II - Synthesis		
Cognitive Modeling	• Recognize patterns (heuristics) • Reduce workload • Predictable response	• See patterns where they do not exist • Premature closure/confirmation bias • Resistant to new ideas
III - Projection		
Anticipation	Predict future events	Incorrect assumptions
Sharing	Increased resources (cognitive/physical)	Need to coordinate a team

Adapted from Endsley MR. Toward a theory of situation awareness in dynamic systems. *Hum Factors*. 1995;37(1):32–64.

VERBAL COMMUNICATION

Effective communication should be a two-way channel and must be both heard and understood. This is highlighted in TeamSTEPPS as the three Cs of communication: (1) Cite names; (2) Clear and concise; and (3) Close the loop. Tested communication tools help standardize and clarify intent, direct team members toward common ideas and purpose, and allow for a safe communication approach during emergencies. Appropriate design of tools is useful to coordinate activities and achieve a shared mental model.

DECISION-MAKING

Critical decision-making, akin to problem-solving, is not innate and should not be left to chance. Humans can only manage about seven pieces of discrete information—less if information processing is required. This is called *working memory*. As expertise improves, cues can be grouped, creating larger effective working memory. Often referred to as *intuition*, it is simply pattern recognition born of knowledge acquisition and experience. Carefully designed training and simulation to enhance cue recognition and appropriate decision-making can be applied across many situations and is paramount to improving outcomes.

TASK MANAGEMENT AND COORDINATION

An accurate shared mental model is crucial for efficient task management and coordination. Both scarce and excessive resources present challenges when managing tasks and coordinating teams. Even in the most austere environments, the smallest team is composed of at least two individuals who work interdependently (and often simultaneously) on task activities toward a common goal. As teams become larger, there is more simultaneous task work, which increases the need for active information-sharing to create an accurate shared mental model and efficient coordination. Task coordination can be either explicit or implicit, but implicit understanding is typically established prior to an event and is the hallmark of high-functioning teams.

An ideal teamwork environment can be encouraged through standardization, continuing education, and regularly scheduled training. Standardization is achieved through institution-specific protocols or guidelines informed by evidence-based best practices. For example, given the ad hoc nature of resuscitation teams, using a standardized and consistent prearrival huddle script provides information about team member capabilities and experience, as well as resource challenges and data specific to the arriving patient. This allows for judicious initial task assignment and care coordination. Similarly, as resuscitation proceeds, certain tasks such as vascular access (circulation) may be performed by the nursing staff, which allows other members of the team, like the physician staff, to take on higher-priority duties (airway, breathing). Likewise, when a team faces a challenge (e.g., access is unsuccessful), effective teamwork requires team adaptation, which may include task switching and choosing an alternative method. This approach can be applied to a multitude of tasks and institutional protocols developed for more effective task switching.

Continuing education, such as that offered by ATLS and Advanced Trauma Care for Nurses (ATCN®), share didactics essential to building shared understanding. Both courses offer skills stations, although as currently taught, these are offered separately. Benefit would be derived from combining skills station activities from both ATLS and ATCN courses. Trial combinations of ATLS and ATCN skills stations prompted sharing of role-specific knowledge, promoted healthy interdisciplinary dialogue, and engendered support for safe communication. Courses specific to team training focus solely on these crucial team skills: Simulated Trauma and Resuscitation Team Training (STARTT), *Trauma Team Dynamics: A Trauma Crisis Resource Management Manual*, and TeamSTEPPS. Finally, regularly conducted, institution-specific, multidisciplinary team simulations boost team coordination and competency. As teams mature through practice and experience, explicit coordination becomes increasingly implicit through a shared understanding of roles, enhancing team performance.

SUMMARY

Inadequate teamwork is among the most common reasons for preventable medical error. Refining team dynamics, much like trauma process improvement, requires continuous effort over time. Indeed, these leadership deficiencies, while sometimes difficult to assess after the fact, should be part of all process improvement endeavors and be assessed during team debriefings.

A scorecard should be developed to help structure such debrief or after-action review discussions. These steps are essential, as focus on nontechnical skills has trailed the tremendous technical advances of the last several decades. Ad hoc resuscitation teams form rapidly, may not know one another, have unknown prior experience, and operate under great uncertainty over compressed time frames. The concepts outlined above can be incorporated into trauma training. This involves preplanning to establish an institutional culture, emphasis on appropriate behaviors that promote effective and safe communication, structured debriefing, and mentored training and simulation. The tools discussed in this chapter provide opportunities to enhance team dynamics and overall effectiveness. **With practice, high-performance teamwork becomes reflexive.**

PHASES OF CARE OVERVIEW

Trauma evaluation and management can be organized into discrete phases of care:

1. Preplanning and administration
2. Prearrival team huddle
3. Arrival handover
4. Initial Assessment team function
5. Departure handover
6. Event debrief

Within each phase, specific tools are provided that, if used effectively, can enhance resuscitation team dynamics and effectiveness.

PREPLANNING AND ADMINISTRATION

Effective trauma teams do not occur by happenstance but are built intentionally from the top down. Hospital leadership must commit to support trauma care by ensuring adequate resources, processes, and systems. At non-trauma-center hospitals, administrative support ensures the presence of appropriate transfer agreements and the ability to care for all patient age ranges (e.g., pediatric readiness). Within trauma centers, surgical leadership, trauma program leadership, and collaborative relationships throughout the institution help ensure that adequate training, guidelines/protocols, and process improvement measures are in place.

Though administrative and leadership support are important foundations for the trauma team, effective teamwork develops through shared vision and collaborative respect. It is not enough to have the equipment, staff, resources, and trauma care guidelines in place; mutual training must also be provided to develop and maintain shared vision and trust. Teams need to drill to ensure skill maintenance and efficiency, as well as promote staff development using an evidence-based program, such as TeamSTEPPS, to optimize team performance.

Practical aspects of preplanning include awareness of facility-specific resource availability. Other factors to consider include the following:

- Who declares a trauma activation, and what are the criteria?
- Is there a checklist or report form to document and share the patient prehospital report?
- What is the contingency plan for trauma patients who arrive without prenotification?
- How many staff could be expected to attend a trauma resuscitation?
- Is there blood readily available? Does the facility have a massive transfusion / hemorrhage protocol (MTP MHP)?
- Is radiology available around the clock?
- Is the operating room (OR) staffed continuously and ready for emergent cases?
- What are the internal resources for emergent obstetrics, pediatric, burn care, or other specialty care?
- How does the facility initiate transfer to specialty care and aeromedical or ground transport?

PREARRIVAL TEAM HUDDLE

Once the team is notified that a trauma patient is en route to the facility, they should do a prearrival huddle. **Although brief, the prearrival huddle is a critical part of preparing for the trauma patient.** As such, leaders of trauma teams should make sure that such a huddle occurs and that all team members give their undivided attention. One way to do this is for the leader to call for quiet during the huddle. Key components of the huddle include the following:

- Emergency medical services (EMS) report—what is currently known about the patient
- Staff introductions—who is present, and what are their roles
- Staff preparation—key staff present, appropriate personal protective equipment (PPE), security presence, etc.
- Clear expectations and goals
- Review of the expected plan for the patient, including possible resuscitation endpoints
- Room preparation—warm room, warm fluids, equipment available and working

Whether an injured patient arrives to the facility without prenotification or is upgraded to trauma status in the triage area, it remains critically important to perform a quick team huddle to confirm key team members' assignments and ensure the best possible coordination of resuscitative care (■ **Table 2-2**).

■ Table 2-2: The Key Components of the Team Huddle.

Team Huddle
Time out/all quiet Full attention of all team members
Introductions
Case Review
Task Assignments
Role & Expectations
Equipment Preparation
Questions/Concerns

ARRIVAL HANDOVER

Clinical handover involves transfer of information, professional responsibility, and accountability between individuals and teams. **An effective arrival handover is one that is delivered succinctly and in a structured manner and that contains only vital data necessary to direct immediate treatment.**

Prehospital providers, including emergency medical technicians (EMTs), paramedics, or other providers responsible for the treatment and transport of injured persons, are the first team members to encounter the patient at the injury scene. These providers have a unique role in reporting initial assessment information about the patient and the environment where the injury occurred. They also provide hemorrhage control and important resuscitative measures (e.g., airway, breathing, and circulation) during transport. Various handover protocols and local practices may influence how clinicians collaborate and communicate during the arrival handover. There are generally three time points for information relay from prehospital providers.

Prenotification: Whether by radio, mobile phone, text message, or communication app, prenotification is often provided while the paramedics are on the scene or during transport. During this period, the prehospital provider may be task-saturated managing a critical patient with few resources and unable to provide all the desired information. The hospital team may need to prepare for the arrival with limited details; however, basic details such as the mechanism of injury, airway status, mentation, and systolic blood pressure can be essential.

Initial arrival handover: One popular handover protocol, the Introduction, Mechanism of Injury, Information related to the complaint, Signs and Symptoms, Treatment given, Allergies, Medications, Background History, Other information, (IMIST-AMBO, ■ **Table 2-3**), provides prehospital providers and hospital clinicians with a standardized process for conducting handovers for all types of patients. Standardized processes must include behaviors that minimize interruptions, reduce the need to repeat information, and allow communication of patient interventions and status to *actively* listening team leaders while maintaining eye contact. Trauma team leaders (TTLs) should be easily identifiable and may wear differently colored attire than the rest of the team. A brief 20–30-second observation period is reserved, like a presurgical time out, as "hands off, eyes on" when the patient remains on the ambulance stretcher and the paramedic delivers the IMIST-AMBO information. After delivering this information to team leaders, the prehospital provider asks if there are any questions about the information delivered. At completion, the patient is transferred from the ambulance stretcher to the trauma resuscitation bed. **An exception is made for patients in critical condition, receiving chest compressions, or those that require manual restraint.** In these cases, it may be appropriate to move the patient without delay. When this occurs, TTLs should coordinate the prehospital providers' IMIST-AMBO report as soon as possible after the patient has been transferred to the trauma resuscitation bed.

INITIAL ASSESSMENT TEAM FUNCTION

In larger centers, trauma teams consist of a minimum of two physicians and three nurses. One physician serves as the TTL, standing at the foot of the bed. The TTL oversees and directs the rest of the team but does not actively participate in procedures or handover care in order to maintain situational awareness and avoid fixation errors. The second physician performs the primary survey and verbally relays results to the team, ensuring that findings and cues are identified and *explicitly declared* for the entire team to hear.

■ **Table 2-3: The IMIST-AMBO Handover Tool.** A popular standardized process for conducting the initial handover of all types of patients between the prehospital providers and the receiving medical facility team members.

I	Identifies the patient's name and age
M	States the immediate clinical situation Mechanism/Medical complaint
I	Provides an assessment of the patient's injuries/background/history information relevant to the complaint
S	Signs, most recent observations
T	Treatment needs identified and Trends in how the patient's condition has changed
?	A period provided for questions allowing for a cross check of information and ensures clinician comprehension

A	Allergies
M	Medication
B	Background history
O	Other information
?	Upon completion of the acronym another period available for further questioning and ensuring the responsibility of the patient has been taken over

Adapted with permission of BMJ Publishing Group Ltd, from Design and trial of a new ambulance-to-emergency department handover protocol: 'IMIST-AMBO', Iedema R, Ball C, Daly B, et al., 21, 2012; permission conveyed through Copyright Clearance Center, Inc.

The three nurses function as a team overseen by the charting nurse, who generally takes up position next to the TTL and helps with task assignment and nursing management. The other nurses fill the roles of medication nurse and procedure nurse, though there may be some overlap in roles depending on the needs of the immediate situation. Many centers add additional team members, which may include but are not limited to an airway physician, a respiratory therapist, and representatives from other surgical specialties and critical care. With this approach, team members can perform concurrent management rather than following a rigid sequential pathway. However, the TTL should use the xABCDE mnemonic to organizing the primary survey.

Any instructions to team members should avoid vague language such as "Let's give more fluid," or "Let's give some sedation," but instead should be directed at a particular team member (Cite names), be Clear, and utilize Closed-loop communication (■ **Table 2-4**). For example, an instruction would be given as, "David, could you please transfuse one unit of packed RBCs under pressure and let me know when the transfusion is complete," and David should confirm by responding with, "I will transfuse one unit of packed RBCs under pressure and let you know when it's complete."

A purposeful, "tactical" pause and summary, or time out, is an excellent way to maintain a shared mental model or collective situational awareness among team members and to elicit input from the team in difficult cases. These pauses are

■ **Table 2-4: The Three Cs of Communication.** Giving direct, specific instructions in a high-pressure clinical environment, helps avoid misunderstandings and reduce medical errors.

C	Cite names
C	Clarity of instructions
C	Closed loop communication

best called for by the TTL in times of transition, such as at the end of the primary survey or following intubation. This helps reorient the team, ensure details are not missed, and establish next priorities. A good summary should include (1) a review of the xABCDEs; (2) an assessment of the current situation; and (3) a plan. For example, "The airway is now secure, and we have decompressed the tension pneumothorax. The patient remains hypotensive despite two units being transfused with a positive abdominal FAST. I believe the patient is in hemorrhagic shock. The MTP has been activated, and we need to prepare the patient for transfer to the OR."

While the TTL maintains overall team leadership, team members should be empowered to speak up if they notice discordant findings or have opinions regarding diagnosis or management. While this is best done during tactical pauses, team members may need to speak up sooner depending on the urgency of the findings. Resuscitations are stressful, and many tools exist to guide team members in avoiding confrontational language (■ **Table 2-5**). These communication skills apply equally to all sizes of teams but may need to be adapted to fit local trauma team models.

■ **Table 2-5: Graded Assertiveness for Speaking Up in Times of Crisis (CUS).** In times of crisis, the CUS approach allows team members to speak up while avoiding confrontational language.

Graded assertiveness for speaking up in times of crisis (CUS).

C	Concerned (e.g., I am concerned we are missing a tension pneumothorax.)
U	Uncomfortable (e.g., I am uncomfortable that the patient is still hypotensive and we don't know why.)
S	Safety Issue (e.g., We need to stop, taking this hypotensive patient to CT scan is unsafe.)

From Pocket Guide:TeamSTEPPS 2.0

When faced with a complicated, multiply injured trauma patient, even the most experienced practitioner can be overwhelmed. ATLS algorithms help simplify and prioritize management. Similarly, the TTL should consider that there are a finite number of destinations for the trauma patient when they leave the trauma/resuscitation bay. At smaller centers where capabilities to manage the patient do not exist, the only destination is transfer to a regional referral center, and the transfer process should be initiated as soon as this lack of capability is recognized (sometimes even prior to or concurrent with patient arrival). For larger trauma centers, destinations for unstable patients are limited to the OR and angiography.

For stable patients, computed tomography (CT) scan is an additional option that may help determine the ultimate destination: ward, intensive care unit (ICU), OR, or angiography. Time spent in the trauma bay should be limited and focused on completing the primary and secondary surveys and any lifesaving bedside procedures, with the ultimate goal of determining which destination is most appropriate for the patient.

Prior to leaving the trauma bay, a final time out should be initiated to review patient status and ensure that all appropriate personnel and equipment are prepared. A standardized checklist can help ensure important details are not missed and can be adapted to one's own center (■ **Table 2-6**).

AIRWAY

Trauma victims often require the individual attention of a person whose role is to manage the airway. During the team briefing before patient arrival, the TTL should identify a clinician with practical expertise to take responsibility for assessing and managing the airway. For example, some doctors in training, such as junior residents, may not have the experience and training in managing difficult airways, such as those associated with inhalation burns or extensive facial trauma. If a person with this expertise does not routinely respond to trauma calls, the TTL should be able to identify someone who can quickly be contacted to assist the team.

If the prehospital information suggests that the patient may require a definitive airway, it may be wise to prepare appropriate drugs for sedation and drug-assisted intubation (DAI) before the patient arrives. Equipment for managing a difficult airway should also be easily accessible from the resuscitation room.

It is important that the airway manager promptly communicate any concerns regarding the airway to the TTL. These may include anticipation of a difficult airway on assessment or changes in airway status. The TTL should ask the airway manager to secure a definitive airway when the need becomes apparent during the primary survey. The timing of definitive airway management may require a discussion between the consultants and the trauma team if there is no urgency to secure a definitive airway. For example, in patients with head injuries who are not in obvious distress, discussion between the neurosurgical member of the team and the TTL may be helpful.

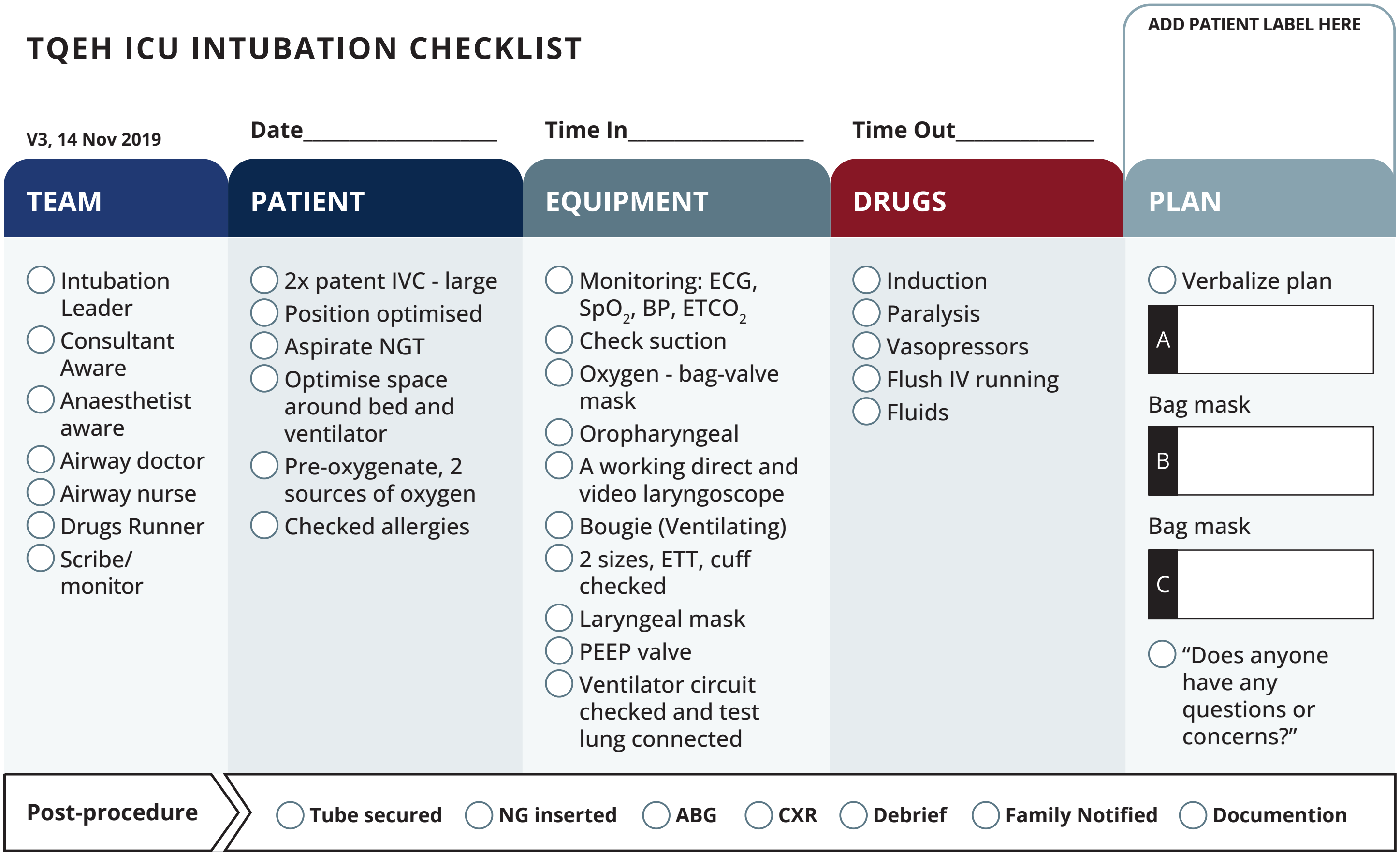
■ **Table 2-6: Pre-Departure Checklist.** Useful for time out before leaving the trauma bay.

Pre-Departure Checklist
○ Is there potential for further airway compromise? ○ If yes, has the airway been secured prior to departure?
○ Have we reviewed chest and pelvis x-rays?
○ Is the patient in shock? If yes, have we notified the trauma surgeon?
○ Are blood products required or activation of the MTP MHP indicated? Indicators: > 4U blood products in 1 hour OR ABC Score >2 OR evidence of shock
○ Have we controlled external bleeding?
○ Is Tranexamic Acid indicated? ○ If yes, administer 2 grams IV
○ Have we recorded temperature and treated hypothermia (T <35°C)?
○ Have we considered analgesia, antibiotics and tetanus?
○ Have we documented the neurovascular status of all 4 limbs?
○ Is vascular access adequate and functional?
○ Do we have all medications necessary for transport?
○ Do we have the transport monitor connected and functioning?
○ Have we updated the family?
○ Have we contacted the receiving unit?
○ Are there any concerns or issues from any team member?

Communication among team members is vital when a definitive airway is placed. The team leader assigns roles in conjunction with the airway manager, depending on the skills and experience of other team members. The airway plan, along with backup plans for any failed attempts, should be communicated to the team. The use of checklists (■ **Figure 2-1**) may aid in communication and ensure the team shares the same mental model. While securing a definitive airway, closed-loop communication between team members is important to ensure that any orders or requests have been completed. Examples of closed-loop communications include confirming with the TTL that the airway person is ready, confirmation of medication names and dosages, confirmation of drug administration, and confirmation that the airway has been secured or otherwise. Patients may require transfer to the CT scan suite, OR, or ICU. Therefore, the TTL should clarify who will be responsible for managing the airway and ventilation during transfer. This is especially important if the patient is mechanically ventilated through a definitive airway.

Any concerns regarding the airway should be documented and communicated while transferring the patient to other teams. This should include the anesthetist if the patient is being transferred to the OR or ICU.

■ **Figure 2-1: TQEH ICU Intubation Checklist.** One example of a checklist that ensures adequate preparation and closed-loop communication between all team members prior to endotracheal intubation.



TQEH ICU INTUBATION CHECKLIST

ADD PATIENT LABEL HERE

V3, 14 Nov 2019

Date__________________ **Time In**_________________ **Time Out**_____________

TEAM

- ○ Intubation Leader
- ○ Consultant Aware
- ○ Anaesthetist aware
- ○ Airway doctor
- ○ Airway nurse
- ○ Drugs Runner
- ○ Scribe/ monitor

PATIENT

- ○ 2x patent IVC - large
- ○ Position optimised
- ○ Aspirate NGT
- ○ Optimise space around bed and ventilator
- ○ Pre-oxygenate, 2 sources of oxygen
- ○ Checked allergies

EQUIPMENT

- ○ Monitoring: ECG, SpO_2, BP, $ETCO_2$
- ○ Check suction
- ○ Oxygen - bag-valve mask
- ○ Oropharyngeal
- ○ A working direct and video laryngoscope
- ○ Bougie (Ventilating)
- ○ 2 sizes, ETT, cuff checked
- ○ Laryngeal mask
- ○ PEEP valve
- ○ Ventilator circuit checked and test lung connected

DRUGS

- ○ Induction
- ○ Paralysis
- ○ Vasopressors
- ○ Flush IV running
- ○ Fluids

PLAN

- ○ Verbalize plan

A

Bag mask

B

Bag mask

C

- ○ "Does anyone have any questions or concerns?"

Post-procedure ○ **Tube secured** ○ **NG inserted** ○ **ABG** ○ **CXR** ○ **Debrief** ○ **Family Notified** ○ **Documention**

The Queen Elizabeth Hospital (TQEH) ICU, Adelaide South Australia. Reproduced with permission.

BREATHING

Prior to patient arrival, the TTL must quickly establish the competencies of team members in performing needle decompression and chest drainage techniques. The status of airway and breathing, including respiratory rate, auscultation findings, and saturation, should be conveyed to the team as part of the arrival handover. Any interventions such as needle decompression or finger thoracostomy should also be conveyed to the team. Any changes in the respiratory status should be conveyed to the TTL by the person performing the primary survey to facilitate appropriate action by the team.

The TTL should recognize which thoracic injuries can or cannot be managed by the receiving institution. Where the injuries exceed the institution's capacity to manage them, arrangements should be made to transfer the patient to the appropriate facility as soon as reasonably possible. These injuries may include major vascular or tracheobronchial injuries or injuries requiring open thoracotomy.

CIRCULATION

Hemodynamic instability related to blood loss from penetrating injury mandates rapid intervention focused on the anatomic location of external wounds. In patients with blunt injury, swiftly narrowing the injury possibilities is crucial for timely and appropriate intervention. As findings are identified, they should be shared with the team to promote a shared mental model of patient status (■ **Table 2-7**). The process of promptly identifying and addressing injuries can be divided into two key areas: physiological response and diagnostics.

Physiological response has three actionable categories:

Responders: Often, 1 L of crystalloid and/or 1 unit of blood/blood components will stabilize this group. These are often patients with long bone injuries contained in a closed compartment or patients with solid organ or soft-tissue injuries that are not actively bleeding. In this situation, the team usually has enough time to complete further diagnostic testing.

■ **Table 2-7: Sites of Blood Loss in Trauma.** A stepwise approach to the identification of possible sources of hemorrhage in the trauma patient.

SITE	DIAGNOSTIC	TIMING	FINDINGS	Comments/Caveats
Abdomen	FAST	Can be performed as a part of the primary survey (xABCDE — FAST)	Positive in any window	A negative FAST is nondiagnostic and should be repeated at intervals in the persistently unstable patient
	Diagnostic peritoneal aspiration (aspiration or lavage)	Usually after excluding hemorrhage in other sites	Grossly positive	Used when other sources of bleeding have not been clearly identified Should only be performed by an available surgeon
Chest	Chest radiograph	As soon as possible after arrival, either during or immediately after primary survey	'White-out' of hemithorax	A wide mediastinum is a danger sign, but not likely active bleeding Pneumonectomy may mimic hemothorax
Pelvis	Pelvis radiograph	As soon as possible after arrival, either during or immediately after primary survey	Pelvis fracture patterns associated with bleeding: open book, vertical shear, lateral compression	
Retroperitoneum	By elimination	Moving to the CT scanner should only occur when there is a modicum of stability and reserved for responders and transient responders	There are no current bedside diagnostics to evaluate this area	This is a closed space and often these patients will be transient responders, allowing time for CT scanning
Floor	Observation/History from field	At time of arrival and during primary survey	Gross blood on the gurney at patient arrival; report from transporting providers	If patient is a transient or non-responder and no gross bleeding is observed, look for other sources
Muscular and subcutaneous tissues; Fracture sites	Rapid TEG, INR, low hematocrit, skeletal x-rays		Discuss TEG INR may not change early Low hematocrit is a late sign, but any low hematocrit detected at first lab draw should raise suspicion for bleeding	This can stem from multiple injuries that are nonsurgical in nature (e.g., scalp laceration, multiple bony and soft tissue injuries), resulting in trauma-induced coagulopathy Low hematocrit may be chronic but could be determined by looking at RBC indices

Transient responders: These are patients likely to have ongoing bleeding from solid organ or soft-tissue injuries and who need timely diagnostics to confirm or exclude injuries in need of urgent appropriate interventions.

Nonresponders: Despite active resuscitation and interventions, these patients mandate rapid, directed diagnostic approaches to facilitate appropriate, emergent interventions and movement to definitive care areas (the OR or interventional radiology suite). In facilities that lack these capabilities, teams must work rapidly to attempt stabilization, promote timely transfer, and inform accepting facilities/clinicians of the greatest potential injuries of concern.

Using a stepwise approach to identify the likely source of bleeding can be very effective. With practice, logical stepwise decision-making can be completed quickly, usually within the first 10–15 minutes after arrival. Pertinent negatives are as valuable as positive findings, allowing teams to eliminate sources of bleeding and focus on the next area of concern to intervene accordingly.

DISABILITY

Traumatic Brain Injury (TBI): In the case of an agitated patient, rapid sequence intubation (RSI) may be required to facilitate safe and efficient evaluation and resuscitation, and the need for RSI may itself be a sign of deteriorating brain injury. This can make subsequent neurological evaluations more challenging. It is important that the team continue to reassess and report on patient status to avoid delayed recognition of neurologic deterioration.

A common pitfall in patients with head injuries is managing scalp lacerations. While these are a seemingly minor concern in the setting of a severe brain injury, they can be a source of exsanguinating hemorrhage and can be controlled with simple measures. The first step is recognition. Well-functioning teams should empower members to speak up to ensure that injuries like this are recognized and addressed.

Spinal cord injury (SCI): In multiply injured patients, keen observation is warranted to detect upper and lower extremity motor issues. Findings must be voiced audibly to ensure team awareness of the potential for impending physiologic deterioration. The need for airway management can be obvious in patients with a high cervical cord injury due to respiratory distress. Patients with lower cervical (C5–C7) or high thoracic (T1–T6) injuries are more challenging, since they often present with little to no obvious respiratory distress and are able to maintain shallow breathing despite their injury. However, up to 30% of these patients will need intubation due to progressive volume loss and atelectasis, which can lead to acute hypoxemic respiratory failure or even death. Team members should be observant of these changes and be encouraged to verbalize their concerns.

Shock in the patient with SCI is hemorrhagic until that cause is excluded. Patients with SCI may not be able to report subjective complaints such as pain; thus, the team must rely on their powers of observation during the Initial Assessment. Reevaluating the patient at scheduled intervals and providing verbal reports may reveal changes pointing to a source of internal hemorrhage.

EXPOSURE AND ENVIRONMENT

All team members should consider environmental concerns that may impact trauma patient care and take the needed steps to protect patients from the impact of exposure and environmental extremes. Understanding potential impacts of exposure and extreme temperatures allows teams to address those needs early (e.g., warm room, warm blankets, heat exchangers, potential for airway compromise).

The EMS prehospital report can provide critical information that assists the trauma team as they prepare to receive the patient. In addition to information about the patient's mechanism of injury, treatments provided, and vital signs, critical information about whether a patient was exposed to extreme conditions or temperatures can be gathered as well, including submersion, prolonged extrication in extreme weather, "found down" status, burns related to specific environments (blast, enclosed space), potential for nonintentional trauma, or exposure to hazardous materials. Based on the exposure information gathered, the TTL and team can plan for likely patient needs and supplies. These include:

Airway—need for emergent airway control/cricothyroidotomy for airway edema; need for warmed ventilator circuit

Breathing—need for escharotomies with circumferential chest burns

Circulation—warmed IV fluids, warmed blood, resuscitation volume needs for burn patients

Disability—Glasgow Coma Scale (GCS) alterations from toxins, hypothermia/hyperthermia, need for fracture management, fasciotomies/escharotomies

Environment/Exposure—quick removal from cold spine boards, removal of wet clothes, active warming measures, time-limited exposure, and quick replacement of warm blankets after patient assessment

Early decision and preparation for transfer to definitive care remain a priority if patient needs exceed center capabilities, especially for burns, pediatrics, obstetrics, and specialty care.

TRAUMA TEAM AND CHILDREN

In nonpediatric-designated centers, the impending arrival of a pediatric trauma patient may trigger levels of team anxiety and stress that are profound. The perceived weakness of an injured child impacts the entire team. Because very young trauma patients comprise a small percentage of the trauma population at most centers, trauma teams may have a confidence gap and thus feel challenged by young trauma victim care.

The adage "Good things come in small packages" may predictably mutate to "scary things" in the absence of good preparation and training. There is no substitute for robust prearrival preparation and planning. Trauma triage and treatment simulation (with video review if possible) of pediatric trauma scenarios measurably strengthen skills, as well as the physical and psychological preparation of the trauma team. Simulation, when followed by critical debriefing to embed efficiencies and best practice models for the team, is an ideal model for practicing skills and understanding team roles and responsibilities.

In the unconscious seriously injured child, the psychological and emotional health of the child may be superseded by that of the trauma team. Strong team leadership, clear communication of priorities, and delegation of critical clinical responsibilities will have the greatest salient effects on the psychological and emotional responses of the trauma team.

In the conscious, more physiologically stable child, basic understanding of childhood response to injury and environment is essential. The concept of the "distracting injury" is well anchored in trauma language and practice. In the injured child, being restrained with a cervical collar, on an immobilizing device, and away from parents and family in prehospital or trauma room locations are all enormously "distracting."

Additionally, it is important to remember that there are substantial numbers of injured children who may have special needs, including learning or neurodevelopmental disability. Information obtained during the initial arrival handover can be particularly important if there is history of one of these conditions. If possible, talk to the child as calmly and clearly as the situation will allow, and judge responses with these potential variants in mind. The emotional environment of the conscious child is important during Initial Assessment. Overly emotional or strident communication is counterproductive and is best minimized.

Tachycardia is an important physiologic sign in injured children. Knowledge of normal ranges of common vital signs for different age groups is important clinical information. Anxiety and the child's emotional response may play a role but should not preclude careful assessment of other causes of sustained tachycardia.

Accurate prehospital information is helpful in preparation for pediatric trauma patients. Accurate weight estimates and vital signs may be challenging in the prehospital setting. The use of adjuncts such as a weight- or height-based pediatric emergency tape are indispensable when there is uncertainty regarding therapeutic options in small children. There are posters available that describe pediatric and infant GCS scoring, formulae for computation of age-appropriate systolic blood pressure, and guidelines for optimal imaging; these are helpful if available in the resuscitation areas. There are also effective algorithms to help with recognition of common patterns of nonaccidental trauma, which is especially prevalent in the infant age range. The age-adjusted pediatric shock index (SIPA) is an effective tool to help triage the severity of injury. Familiarity with this tool is a tested method to assess severity of hypovolemia from injury.

Family members in the pediatric trauma resuscitation room may be of huge benefit to the injured and anxious child. If the family or caretakers do not materially interfere with the care being provided by the trauma team, they may help with communication, historical information, or support. Injured and emotionally fragile children will typically mimic the level of the most emotional family member present. It is important to assess a family advocate's ability to maintain a calm and supportive demeanor. Displays of volatile or stressful emotional response will often be mirrored by the child. Conversely, parental detachment or disinterest may be warning signs of child maltreatment or neglect.

TRAUMA TEAM AND THE PREGNANT PATIENT

Treating a pregnant trauma patient can amplify the stress of the Initial Assessment and generate powerful emotional responses from team members. Successful assessment and management of the pregnant trauma patient requires knowledge of and attention to pregnancy-specific physiologic changes, knowledge of the spectrum of potential injuries, and appropriate early integration of obstetrical services into the trauma team, with preparation for extreme cases that may require rapid obstetrical intervention. Maternal trauma can result in significant and sometimes occult or delayed consequences to the fetus (■ **Table 2-8**).

Care of the pregnant trauma patient requires coordination of a multidisciplinary team. To ensure optimal management, care must be coordinated between the TTL and the obstetrical service. Strategies to achieve this include the use of clear activation criteria, institutional obstetric emergency teams that can respond to the trauma venue, or, in the absence of an available obstetrical service, practice guidelines appropriate to location. The importance of interprofessional team function and use of CRM skills is increasingly recognized, and the use of simulation to help improve the performance of obstetrical teams in such situations has been demonstrated to be effective.

Initial evaluation of a reproductive-age woman should include a concise and focused obstetric and gynecologic history and ensuring that universal pregnancy testing is performed. In some instances, early pregnancy may be diagnosed using point-of-care ultrasound. Approach to the female trauma patient can be stratified as follows: (1) potentially pregnant; (2) pregnant at less than 20 weeks' gestation (or local standards for viability); and (3) pregnant at greater than 20 weeks' gestation (or local standards for viability) (■ **Table 2-8**).

Verbal confirmation by the TTL will help focus team efforts. Fetal viability is achieved at approximately 23 weeks' gestation, at which time maternal resuscitation and fetal assessment should take place concurrently. Perimortem delivery is recommended within 4 minutes of arrest with the goal of fetal delivery within 5 minutes of arrest, while resuscitation is continued. The need for early delivery (not perimortem C-section) should be based upon mutual decision-making between obstetric and trauma specialists and should include patient input to ensure appropriate consideration is given regarding implications related to mode of birth, outcomes related to prematurity, and other relevant points based on individual circumstances.

Minor injuries in pregnant patients can pose a risk to the fetus. These typically manifest within 4–6 hours of presentation and require monitoring with cardiotocography by a team member with experience in recognition of uterine contractions and fetal heart rate interpretation.

DEPARTURE HANDOVER

The departure handover occurs when the patient is transferred to a different location/department within the hospital (e.g., OR, ICU, ward) or to an outside facility when in-house resources are not available to meet the patient's needs. Developing a standard reporting format is central to consistent and reliable information sharing. The foundation of this report is to communicate the most relevant information in a concise yet comprehensive manner.

The handover includes both written documentation and verbal communication and should include the circumstances of the injury, details of the resuscitation, relevant physical findings, pertinent imaging and laboratory data, specific treatments, current clinical condition, anticipated areas of concern, and pertinent medical history. Several structured, standardized handover tools exist to achieve this objective, such as S-xABCDE-BAR, as outlined in *Chapter 1, Initial Assessment: Primary Survey,* in *Chapter 15, Transfer to Definitive Care.*

Closed-loop communication is important to ensure that the receiver understands the information, and the reporter should provide the opportunity for questions and leave a callback number to ensure optimal patient care. Centers should monitor adherence and embed this process into routine educational offerings to ensure acceptance.

Table 2-8: Trauma in Pregnancy Toolkit. Evaluation of the female trauma patient of reproductive age.

TRAUMA IN PREGNANCY TOOLKIT

ACTIONS

Team Awareness	Concerns	Team Actions/Shared Knowledge
Stages of Pregnancy	Potentially Pregnant	• Confirm pregnancy test obtained, report results aloud • Obstetrical and gynecologic history: include GTPAL (total gestations, term gestations, preterm gestations, abortions, and living children); prior surgery; obstetrical care to date; knowledge of Rh status • Assess uterus during primary survey • Uterine fundus above umbilicus correlates with > 20 week gestation
	Suspected or known: <20 weeks (or local standard for viability)	• Maternal resuscitation per nonpregnant patent • Obstetrical consult and fetal ultrasound if available • Fetal maternal hemorrhage test (Kleihauer Betke, flow cytometry) • Electronic fetal monitoring if available and recommended by Obstetrical Team • Focused obstetric history (ideally obtained with obstetrical team) using “CODE” mnemonic: Complications of Pregnancy; Obstetric history and prenatal care; Dating method/Estimated Due Date; Event details, including leaking, bleeding, contractions, fetal movement
	Suspected or known: >20 weeks	• Concurrent assessment of mother & fetus • Lateral lift tilt or manual uterine displacement • Point-of-care ultrasound where available may be used to confirm the presence of fetal heart activity • Be ready for emergency C-section • Electronic fetal monitoring (if available)

FOR TEAM AWARENESS

Team Awareness	Concerns	Team Actions/Shared Knowledge
Psychological	Increased team anxiety	• Call for additional assistance • Guidelines for obstetrical activation
	Two teams/Two patients	• Develop roles/responsibilities checklist with obstetrical team • Stratify approach by gestation • Systematic collaborative resuscitation • Multidisciplinary simulation-based training
Physiological	Shock less evident	• Hypervolemic, hyperdynamic at baseline • Dilutional anemia • Normocapnea is an early sign of ventilatory compromise
	Fetal distress	• Early fetal heart rate monitoring as an additional vital sign • Early indication of maternal distress
	Rh status	• Fetal maternal hemorrhage test on all pregnant patients • Rh immune globulin on all Rh-negative patients • If unable to obtain Rh status, administer immune globulin
Radiation exposure	Protect fetus when able	• Prioritize optimal resuscitation of mother • Obtain imaging as clinically indicated
Emergency C-section delivery	Time matters	• Initiated within minutes of arrest and fetal delivery within 5 minutes • Do not waste time for fetal heart tones or ultrasound • Vertical incision in abdomen and uterus • May improve maternal survival even if fetus <20 weeks • Notify neonatal ICU team if available • Multidisciplinary simulation-based training

Minor maternal injury/Obstetrical complications/Other	Occult fetal consequences	• Minimum of 4-6 hours of cardiotocographic monitoring/electrical fetal monitoring, ultrasound, consider:
		  • Premature rupture of membranes
		  • Preterm labor
		  • Placental abruption
		  • Uterine rupture
		  • Screen all women of childbearing age for intimate partner violence

EVENT DEBRIEF

Debriefing is defined as *a reflective conversation about performance*. Allocating time for a debrief following trauma resuscitations can be beneficial to (1) address team member stress; (2) identify strengths in management; (3) identify areas in need of improvement; and (4) improve team functioning while building mutual respect and empathy.

To be most effective, debriefs should be structured and constructive. Having a guided debrief is more effective than unguided ones; thus, facilities should develop specific features to be included in the debriefs and build a structure where those facets are discussed. The Promoting Excellence and Reflective Learning in Simulation (PEARLS) framework presents a simple, easy-to-learn technique that can be helpful to structure debriefs. This framework consists of setting the scene and creating a safe context to facilitate learning. The facilitator then obtains reactions from participants, exploring their feelings. At this stage, facts are clarified before analyzing the performance. This type of approach may be useful for longer debriefs, but when time is limited, even a quick reactions phase ("How did that feel?") followed by a simple plus/delta ("What went well? What would you do differently next time?") is probably adequate, though this is an area in need of further study. Debriefs should never be seen as punitive or place fault on an individual but should instead be focused on identifying gaps that could improve team function and, ultimately, patient care. As such, it is important that a psychologically safe environment be built when rolling out a debriefing process.

Debriefing can occur immediately following a resuscitation (a "hot" debrief) or in a delayed fashion (■ **Table 2-10**). While delayed debriefs may be required for critical incidents and very traumatic events, immediate debriefs are more practical for most situations. It is important to set aside time for the debrief; otherwise it is unlikely to happen. The TTL is an obvious choice to facilitate the debrief, but any team member could be assigned this role. Having an accepted process and role clarity is more important than the background of the facilitator. Training is helpful for facilitating a multidisciplinary group debrief in order to ensure that the conversation isn't dominated by one or two individuals and that all priorities are addressed. Such training should demonstrate to leaders the merits of conducting such debriefs and provide them the tools and techniques they will need to conduct effective debrief sessions.

■ **Table 2-10: TAKE STOCK Debrief Tool.** One example of a structured debrief tool that can be used by the trauma team following a resuscitation.

TAKE STOCK Debrief Tool	
T	Take an instruction sheet
A	Ask "Is everyone OK?"
K	Know if anyone needs a break
E	Equipment issues?
S	Summarize the event
T	Things that went well?
O	Opportunities to learn?
C	Cold debrief necessary?
K	Know who is present

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GOALS OF CARE AND COMMUNICATION OF SERIOUS NEWS

An unfortunate reality is that not all patients with trauma will survive their injuries. Data suggest that about 1%–2% of all transfers to a trauma center either die or are palliated without any operative, endoscopic, or radiological intervention. This may increase the burden on referring and receiving centers, medical transfer services, and families and loved ones, especially if the receiving center is a long distance away.

However, predicting trauma outcomes is an inexact science. In patients with injuries thought to be potentially nonsurvivable, communication between the healthcare team, the family, and the accepting transfer facility is critical. Goals of care discussions should include the patient's preexisting wishes (if known) and should be initiated once there is enough information regarding the nature, likely impact, and expected course of the patient's injuries. In many cases there will not be enough information about this at the initial receiving facility, and clinicians should be honest with the patient and family about what they do and do not know. This is particularly true when prognostic determinations will require specialist input not available at the initial receiving facility.

Discussions around limitations of care and palliation are difficult. There are a variety of models to guide this communication; one approach is outlined in *Chapter 20, Communicating Serious News in the Acute Trauma Setting.*

CHAPTER SUMMARY

Ad hoc trauma resuscitation teams operate under great uncertainty over compressed time frames. Exceptional teams are built through focused training of nontechnical skills to promote healthy interaction. This requires continuous effort over time. The concepts outlined above should be incorporated into multidisciplinary trauma training and become part of the institutional culture. With practice, high-performance teamwork becomes reflexive.

KEY LEARNING POINTS

- **High-functioning resuscitation teams are developed through multidisciplinary training of nontechnical skills.**
- **Adopting the tools provided in this chapter will enhance the effectiveness of team dynamics at each phase of care: Prearrival huddle, arrival handover, initial assessment, departure handover, and event debrief.**
- **Closed-loop communication, tactical pauses, use of call-outs, and graded assertiveness promote psychological safety and better team situation awareness.**
- **With practice, high-functioning team performance becomes reflexive.**

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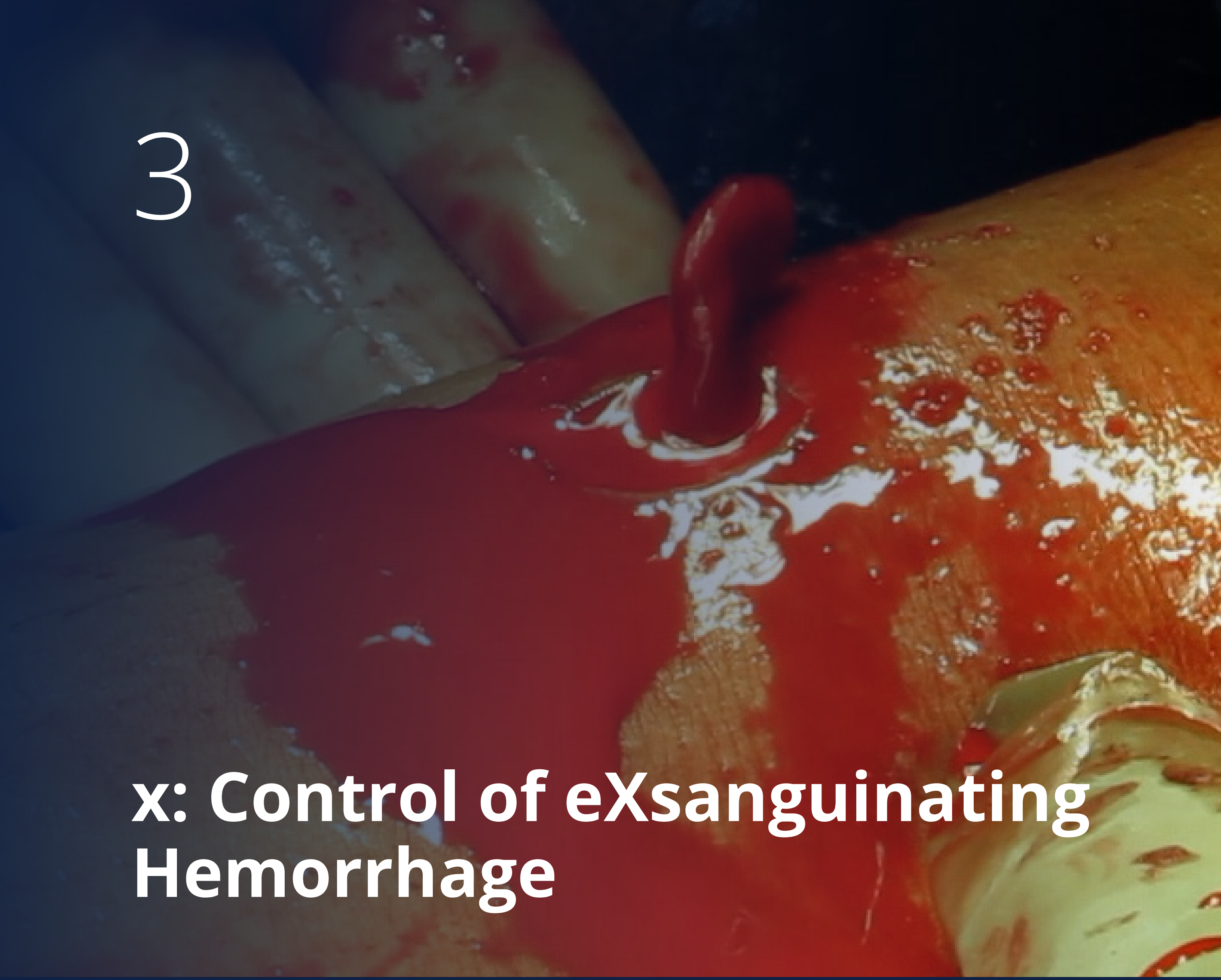


3

x: Control of eXsanguinating Hemorrhage

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course manual, you will have the ability to do the following:

1. Identify life-threatening compressible external hemorrhage
2. Initiate tiered emergent external bleeding control
3. Evaluate indications for, and describe application of, an extremity tourniquet

3

Control of eXsanguinating External Hemorrhage

CHAPTER STATEMENT

Massive external hemorrhage represents an immediate threat to life. Stopping exsanguinating external bleeding through direct pressure, wound packing, and/or tourniquet application is the first step in the primary survey of the trauma patient.

INTRODUCTION

Treat the greatest threat to life first. Rapid trauma primary survey consists of a systematic approach to identify and mitigate life-threatening conditions. **In some scenarios, massive external hemorrhage, such as occurs with extremity and other open wounds, may represent the greatest threat to life.** A focus on stopping compressible, life-threatening external bleeding is supported by data reporting improved outcomes.

Tourniquet use was recognized as an effective method to control hemorrhage during the World Wars. However, prolonged tourniquet application led to amputations of potentially viable limbs, rhabdomyolysis, and neuropathies. Thus, through the latter half of the 20th century, tourniquet use almost disappeared from military and civilian practice. During the 1990s and the early 21st century, tourniquets were reassessed and adopted throughout the US military, with an 85% decrease in deaths due to extremity hemorrhage.

Civilian prehospital tourniquet use lagged military adoption. The Sandy Hook tragedy and the Hartford consensus occurred at the same time the success of military tourniquets was confirmed.

The Bleeding Control Basic (B-Con) course for the public was released in 2014. B-Con was successful beyond expectations and transitioned into the Stop the Bleed® program. Subsequently, tourniquets became a standard component of trained first responder, bystander, and emergency medical service (EMS) equipment. Bleeding control kits are frequently located next to automatic defibrillators in public areas. Several studies have documented a lower rate of mortality, blood transfusion, and complications following tourniquet application. If tourniquet duration is less than 2 hours, there does not appear to be an increased rate of amputations or other tourniquet-related adverse events.

The "x" step of xABCDE does not diminish the importance of airway assessment and maintenance, nor does it represent a full assessment of circulation. The "x" step is a quick evaluation for massive (i.e., active, large-volume, and continuous) external blood loss. When present, massive external compressible hemorrhage is immediately controlled upon patient arrival. Bleeding control interventions are lifesaving, take seconds to initiate, and may be provided while other team members simultaneously proceed to initial basic airway management. An xABCDE protocol has recently been associated with improved survival over an ABCDE protocol in one prehospital study.

ASSESSMENT

Traumatic hemorrhage can be divided into compressible and noncompressible types. Compressible hemorrhage may be defined as bleeding that is visible and potentially controllable without making an incision, employing methods such as pressure, packing, and tourniquet application. Compressible hemorrhage may be due to an extremity injury or a massively bleeding nonextremity wound. The clinician visually inspects the patient, clothing, and stretcher, searching for continuous large-volume bleeding, pooling of blood, and spurting arterial hemorrhage. In many trauma scenarios, external visible bleeding is not large in volume, is not spurting from a larger artery, or was adequately controlled during prehospital management. **In situations of non-life-threatening external hemorrhage, the clinician proceeds to the airway assessment and management step of the primary survey.**

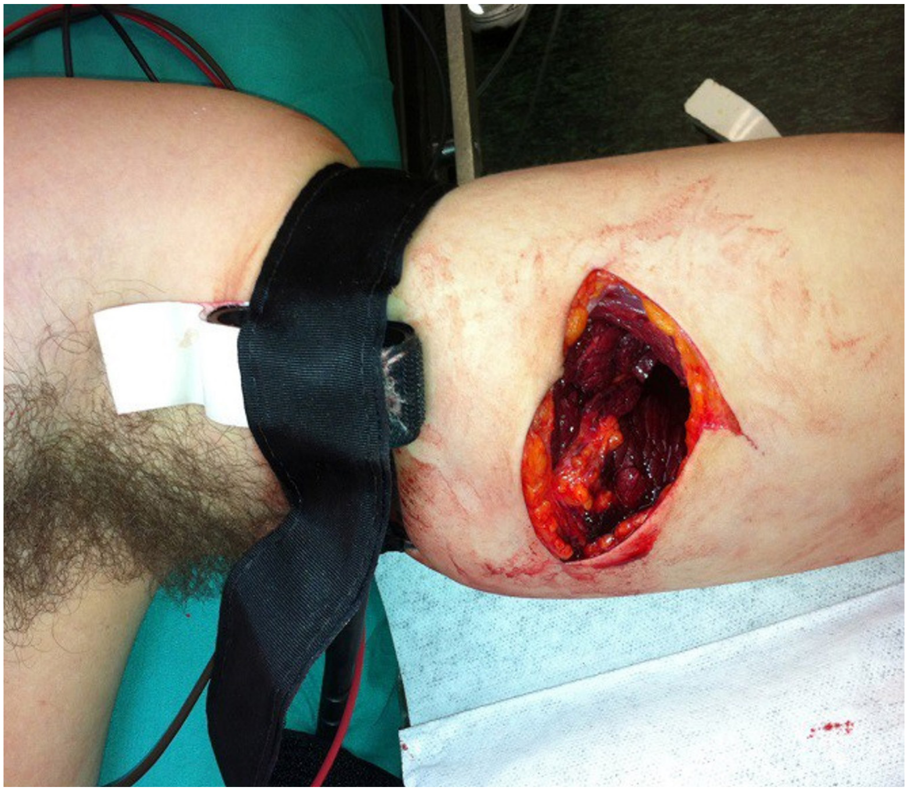
MANAGEMENT

The area of exsanguination is completely exposed. All clothing is removed around and proximal to the injury. Direct pressure is applied with a gauze dressing as precisely as possible over the site of bleeding. Larger and deeper wounds are packed with gauze while pressure is applied. If bleeding control is accomplished, a pressure dressing is applied and the wound is observed for resumption of hemorrhage while other steps of the primary survey are completed. Most trunk wounds and scalp lacerations are temporarily controlled with gauze, packing, and pressure. **If extremity bleeding control is not rapidly achieved with direct pressure and wound packing, a tourniquet is applied.** Blind clamp placement into wounds is not performed.

TOURNIQUET APPLICATION

A tourniquet is applied if extremity bleeding is not rapidly controlled with pressure, if "spurting" arterial hemorrhage is visualized, or if a complete or near-complete amputation has occurred. **The tourniquet is applied 2–3 inches (5–8 cm) proximal to the bleeding site and not over a joint.** At a healthcare facility, preferably all clothing surrounding the injury has been removed, and the tourniquet is applied directly on skin, not over clothing (■ **Figure 3-1**). The tourniquet is tightened sufficiently to overcome systolic blood pressure. **A pulse should not be palpable distal to the tourniquet following application, and bleeding should cease. The tourniquet is painful when tightened adequately.** If bleeding continues, a second tourniquet is placed 2–3 inches proximal to the first device. **Importantly, time of application is recorded, preferably on the device itself.**

■ **Figure 3-1: Extremity Tourniquet and Application.** An extremity tourniquet applied 2-3 inches (5-8 cm) proximal to the bleeding site, on skin, not over clothing, and not over a joint. The tourniquet is tightened sufficiently to overcome systolic blood pressure.



Following completion of the primary survey and adequate resuscitation, assessment for tourniquet conversion is performed. *Tourniquet conversion* is the deliberate process of exchanging a tourniquet for another method of hemorrhage control. Please see *Chapter 14, Initial Assessment: Secondary Survey*, for the procedure of tourniquet conversion.

NONCOMPRESSIBLE HEMORRHAGE

Hemorrhage within the chest, abdomen, and pelvis cavities, as well as at junctional locations (i.e., too proximal on an extremity for tourniquet application), is considered noncompressible. Junctional tourniquets are being evaluated for efficacy. At present, inadequate clinical experience and data exist. Control of pelvic hemorrhage by application of external pelvic devices will be covered in *Chapter 6, Circulation Assessment and Volume Resuscitation*. Data and indications for catheter-based vascular occlusion devices (e.g., resuscitative endovascular balloon occlusion of the aorta, REBOA) are evolving. These advanced techniques are beyond the scope of ATLS®.

CHAPTER SUMMARY

Treat the greatest threat to life first. Massive external hemorrhage may represent the greatest threat to life. A quick evaluation and stopping of compressible exsanguinating external bleeding comprise the "x" step of xABCDE. Active, large-volume, continuous, compressible external hemorrhage is immediately controlled upon patient arrival through tiered application of direct pressure, packing, and tourniquet application. A distal pulse is not present following proper application of an extremity tourniquet. Bleeding control is lifesaving, takes seconds to perform, and is provided while other team members simultaneously provide initial basic airway management.

KEY LEARNING POINTS

- **Uncontrolled massive external hemorrhage represents a great and rapid threat to life.**
- **Immediate identification and control of exsanguinating external hemorrhage is the "x" step of the xABCDE primary trauma survey.**
- **A tiered application of direct pressure, wound packing, and tourniquet application is performed to manage exsanguinating external hemorrhage.**
- **A tourniquet is tightened until bleeding stops. A distal pulse is not palpable when a tourniquet is adequately tightened.**
- **The time of tourniquet application is recorded, preferably on the device.**

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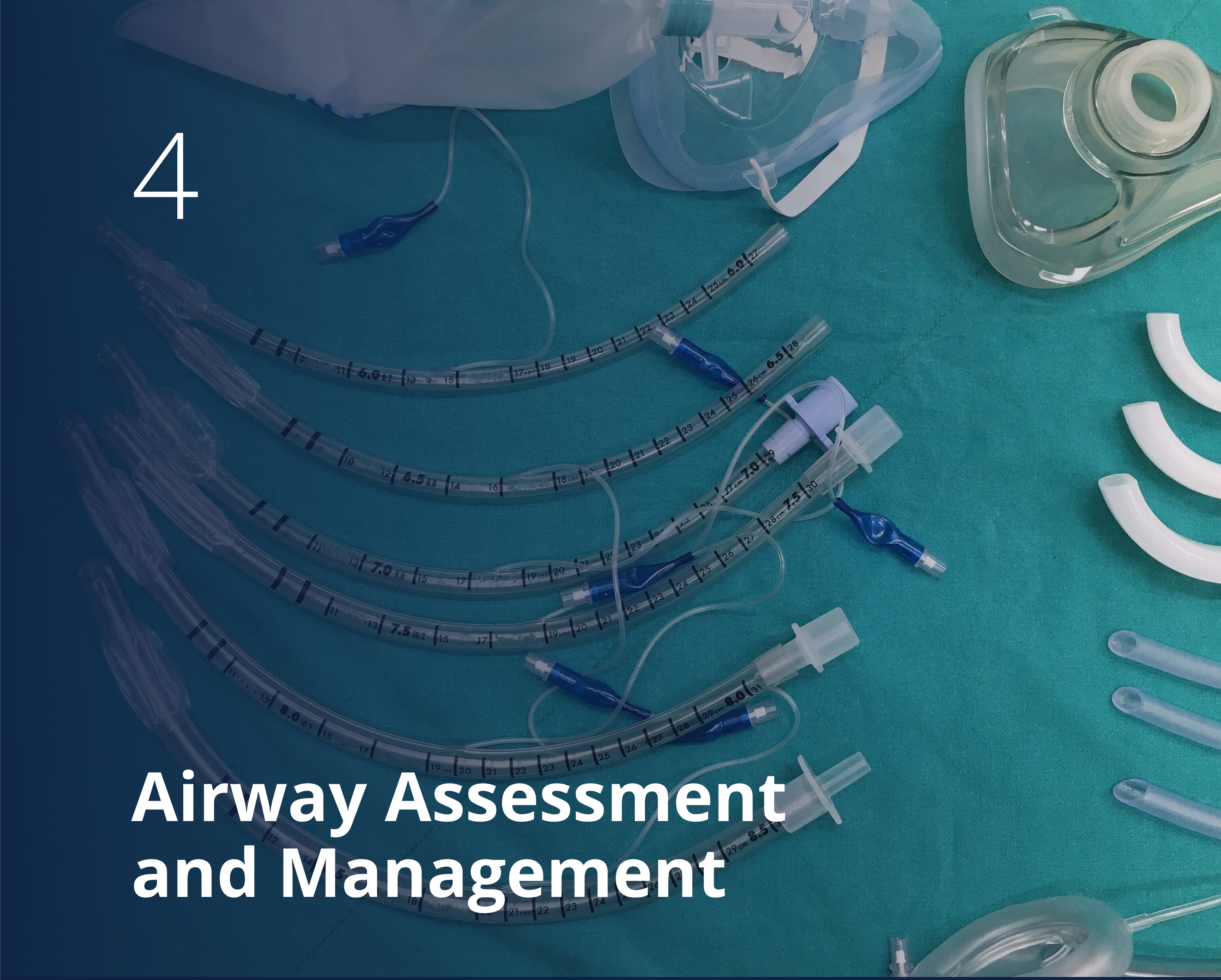


4

Airway Assessment and Management

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Describe the critical role of airway management in trauma care and the importance of ensuring adequate oxygenation and ventilation in trauma patients
2. Explain the indications for various airway management techniques as a range of airway interventions, from basic maneuvers to advanced procedures and explain when each is appropriate
3. Describe the concept of an individualized and context-based approach to airway management and explain modifications of airway management strategies by considering the patient's specific injuries, airway anatomy, and physiology; the expertise and training of the ATLS clinician and team; and the management environment, including available equipment and human resources
4. Describe an approach to anticipate, identify, and manage potential complications in airway management including an inability to intubate
5. Explain application of the principles of safe airway management including use of continuous monitoring, planning, and cognitive aids.
6. Describe adaptation of airway management techniques to specific patient populations including pediatric, obstetric, and larger patients
7. Explain management principles of airway injuries and burns
8. Discuss development and implementation of team-based approaches to airway management

4

Airway Assessment and Management

CHAPTER STATEMENT

Airway management is a fundamental aspect of trauma care. Meticulous planning and flawless execution are important to ensure patient safety. Ensuring adequate oxygenation is a primary goal, understanding that not all patients benefit from immediate intubation.

Airway management interventions may be considered on a spectrum, ranging from basic airway maneuvers and upper airway devices to subglottic airways (tracheal intubation and surgical/incisional airways). A modified rapid-sequence intubation (RSI) technique is recommended for tracheal intubation in trauma scenarios, with preoxygenation, apneic oxygenation, and confirmation of successful tracheal intubation as critical components. Checklists, cognitive aids, and well-organized equipment enhance team performance in high-stress airway management situations.

INTRODUCTION

Trauma patients may present with injuries or burns affecting the airway or adjacent structures. Airway assessment and management are important due to the systemic effects of trauma, particularly in neurological and respiratory injuries. Managing the airway involves a balance between a swift intervention and a thoughtful approach. While compromised airways can result in significant morbidity and mortality, interventions can sometimes exacerbate a partially obstructed airway, leading to complete blockage. Airway management failures account for 8% to 15% of potentially preventable trauma deaths.

A 2011 audit in the United Kingdom revealed that even among specialist clinicians within advanced healthcare systems, catastrophic complications related to airway management can occur. These complications may be prevented through training and following protocols. The 2021 INTUBE study provided additional insights into global airway management complications. Cardiovascular instability was common, and the study highlighted areas for improvement, including equipment selection and guideline adherence. Sentinel cases of death under anesthesia due to airway complications serve as stark reminders that even experienced airway clinicians in elective scenarios must remain vigilant and be prepared.

Safe airway management is achieved through individual and team training, continuous physiological monitoring, proactive planning for potential failures, early problem recognition, and excellent teamwork and communication. **Less-invasive upper airway techniques may provide adequate airway management until appropriate expertise is available to perform endotracheal intubation or other advanced maneuvers.**

This chapter promotes an individualized and context-based approach to airway management, considering the following:

- The presenting injuries, airway anatomy, and physiology
- The ATLS® clinician and team level of expertise, experience, and training
- The management environment, available equipment, human resources, and access to specialized assistance

Managing injuries or burns to the airway can be very challenging, even for experienced clinicians. In such instances, early consultation with specialist surgeons and/or critical care physicians is important.

This chapter serves as an introduction to airway management in trauma. It is not intended to replace clinical training, expertise, and judgment, nor does it seek to limit the practice of airway management specialists who apply their expertise in a different fashion than described in this chapter.

ANATOMY AND PHYSIOLOGY

The airway includes the nasopharynx and oropharynx, the laryngeal structures, the trachea, and the progressively smaller divisions of the airways in the lungs. Airway management focuses on ensuring patency to the level of the trachea. Injuries can occur to the more distal airways, especially the main bronchi.

The primary physiological functions of the airway are, in order of importance in trauma management:

- To provide oxygenated air to the lungs (oxygenation)
- To remove carbon dioxide (CO_2) from the lungs (ventilation)
- To protect the lungs from foreign material, including food, fluids, secretions, and regurgitated gastric contents (protection against pulmonary aspiration)

In airway management, maintenance of oxygenation has the highest priority, as permanent systemic injury can occur within minutes of inadequate oxygen. In normal physiology, reduced CO_2 clearance is frequently well tolerated, but this tolerance may decrease in critical illness, particularly in traumatic brain injury (TBI). Pulmonary aspiration can impair oxygenation and ventilation and lead to pneumonitis or pneumonia in a more delayed fashion.

PATHOPHYSIOLOGY

AIRWAY INJURIES AND PATHOLOGIES

Direct injuries to the airway, while infrequent, present significant management challenges. Laryngeal, tracheal, or maxillofacial fractures can distort normal airway anatomy and severely impact management. Positive-pressure ventilation, passage of endotracheal tubes, and surgical intubation may complicate airway injuries (e.g., lacerations or transections) or create false passages. A multidisciplinary approach involving surgeons with maxillofacial expertise is beneficial. Intracranial injuries are commonly associated with facial trauma and are often an indication for early airway management.

Clinical findings suggestive of significant laryngotracheal airway injury include dysphagia, hoarseness, stridor, subcutaneous or mediastinal emphysema, loss of laryngeal prominence, laryngeal tenderness (with pain disproportionate to examination findings), crepitus, cartilaginous asymmetry, ecchymosis, expanding hematoma, or open penetrating injuries. Continuous air leakage into the subcutaneous tissue may occur with trachea-bronchial injury. This leakage is exacerbated by positive-pressure ventilation and may extend to the pleura, mediastinum, neck, chest/abdominal wall, and throughout the body.

Multiple maxillofacial and/or mandibular fractures may disrupt structural bony integrity with resultant soft-tissue collapse and airway obstruction. This obstruction may be more pronounced when the patient is in a supine position. Condylar fractures may cause mechanical obstruction and trismus (limited mouth opening), creating challenging or near-impossible oral airway management. Airway bleeding can accompany any injury, further complicating treatment. Depending on location and severity, airway bleeding may represent an existing or potential emergency. Management focuses on obtaining an open airway and controlling or stopping the bleeding.

Assessment of airway injuries includes a history (mechanism of injury and symptoms), examination (searching for the signs of airway compromise mentioned earlier), and possibly more advanced investigations of the airway. Flexible endoscopy (nasoendoscopy), if available, may visualize the larynx and be valuable in assessment of suspected laryngeal injury or airway burns. Various potential imaging modalities are discussed later in this chapter (see Adjuncts to Assessment).

Management of each patient with airway injuries is unique, making global recommendations challenging. Administration of supplemental oxygen, if available, while awaiting expert advice may be appropriate**. Patients with multiple facial and airway injuries often assume the most comfortable and efficient airway position, frequently sitting upright. These patients are allowed to maintain this spontaneous effective position, even if other injuries are suspected.** Cervical spine collars, when indicated, are adjusted to avoid airway obstruction. **Airway edema from multiple injuries may progress and lead to obstruction over time. Continuous observation and reassessment are crucial, with the trauma clinician prepared to immediately intervene to maintain airway patency.**

Tracheal intubation may be indicated. To prevent further injury, invasive maneuvers are performed as gently as possible, with surgical/incisional airway equipment prepared. The safest airway may be an awake tracheostomy performed by a qualified surgeon. However, this resource may not be available in the ATLS context.

AIRWAY BURNS

The patient with airway burns may present with a patent airway. However, progressive edema can cause airway obstruction. Airway management will be significantly more difficult in the presence of impending obstruction. Early intubation is sometimes warranted. The clinician continuously evaluates and reevaluates if the patient is best treated with early intubation or is better managed with frequent monitoring and reassessment. The decision to intubate the airway may be complex. When time allows and resources are available, burn center consultation may be beneficial.

Urgent intubation is generally indicated in the presence of these signs of potentially imminent airway obstruction:

- Decreased level of consciousness
- Dyspnea
- Decreased oxygen saturation (SpO_2)
- Stridor
- Suprasternal, substernal, or subcostal retraction
- Full-thickness facial burns
- Edema of oral structures and/or the tongue

Clinical factors that raise the potential for airway challenges in burn trauma include a history of confinement in a burning environment; inhalation of smoke, heated gasses, and/or toxic chemicals (e.g., burning foam in furniture, industrial locations); singed facial or nasal hairs; carbonaceous deposits in the mouth; hoarseness; dysphagia; drooling; carbonaceous sputum; wheezing; and large body surface area burns, which will be complicated by the development of edema during resuscitation. However, these signs are neither sensitive nor specific indications for urgent intubation. They are indications for frequent monitoring and reassessment. When expertise and equipment are available, nasoendoscopy may be useful in assessing airway burns. Toxicity from carbon monoxide (CO) or cyanide (produced by plastic combustion) is relatively common. Specific therapy is further outlined in *Chapter 9, Thermal Injuries.*

ASSESSMENT

PERSONAL PROTECTIVE EQUIPMENT (PPE)

The PPE for airway management is identical to that for other trauma management (see *Chapter 1, Initial Assessment: Primary Survey*). Eye protection and a mask are important due to the potential for direct exposure to exhaled secretions.

INDICATIONS FOR AIRWAY INTERVENTION

General indications for airway management during the primary survey are summarized in ■ **Table 4-1**.

■ Table 4-1: Indications for Airway Management During the Primary Survey.

Airway	Partial or complete airway obstruction Anticipated or impending airway obstruction (e.g., direct trauma, hemorrhage, or burns)
Breathing	Severe chest injury with respiratory failure Significant hypoxia (SpO_2 <90%) despite high-flow oxygen, after exclusion of pneumothorax Hypercapnia from hypoventilation, without an immediately reversible cause (e.g. due to neurological or respiratory failure)
Circulation	Altered mental status due to shock
Disability	Severe TBI with GCS score 8 or lower
Exposure	High percentage body surface area burns

SpO_2: Pulse oximetry. TBI: Traumatic brain injury. GCS: Glasgow coma scale

ASSESSMENT OF THE AIRWAY IN TRAUMA PATIENTS

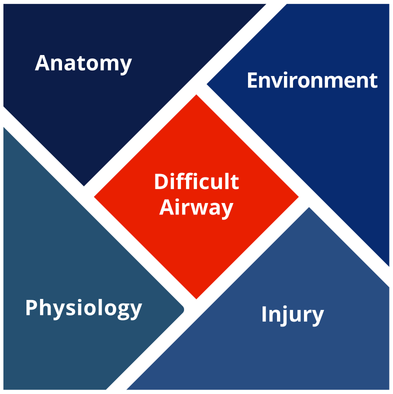
A thorough, rapid, and accurate airway assessment is important. As illustrated in **■ Figure 4-1**, several factors can create challenging airway management in trauma patients, including the following:

- Anatomy—individual variation
- Physiology—derangements
- Environment—practice factors (equipment availability, team training and dynamics, cognitive load, individual experience)
- Injury—direct airway trauma

Airway interventions exist on a spectrum starting at basic airway maneuvers, proceeding through upper airway devices, and culminating at subglottic airways (tracheal intubation and surgical/incisional airways). A subglottic device is not mandatory for all patients. An anatomical airway assessment aims to predict difficulty in performing any of these techniques. Assessment of physiology is also important in formulating an airway management strategy. A reassuring assessment does not exclude the possibility of a difficult airway.

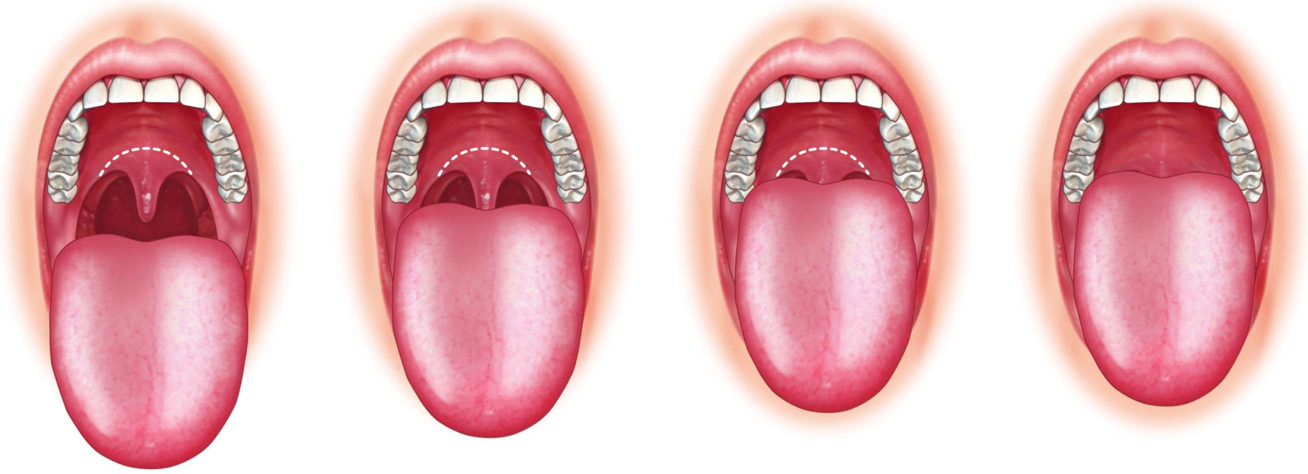
Preparation involves planning for procedural failure and complications. Nonpatient factors, including practice environmental conditions (ergonomics, noise, lighting), equipment, the level of individual and team familiarity and training, and other human factors can also challenge airway management. Therefore, **airway management in trauma patients always has the potential to be difficult.**

■ Figure 4-1: Factors Contributing to Airway Managament in Trauma. The confluence of these factors illustrates that the potential for difficulty with emergency airway management is always present.



Assessment of airway anatomy includes a history, examination, and investigations. Historical factors predictive of difficulty include previous difficult airway management (strongly predictive), pregnancy, obstructive sleep apnea, and previous radiotherapy or surgery to the airway or neck. Predictive features on examination include obesity, large or abnormal neck anatomy, a short thyromental distance, retrognathia, limited neck mobility (including spinal motion restriction), the presence of a beard (during mask ventilation), restricted jaw movement (mouth opening and jaw protrusion), and limited space inside the mouth.

■ Figure 4-2: The Mallampati score. Employed in less emergent situations, this scoring system predicts airway management difficulty based on the structures visible. The patient is asked to open the mouth and protrude the tongue without phonating. **Class I:** soft palate, uvula, fauces, pillars entirely visible; **Class II:** soft palate, uvula, fauces partially visible; **Class III:** soft palate, base of uvula visible; **Class IV:** hard palate only visible.



Class I: soft palate, uvula, fauces, pillars visible

Class II: soft palate, uvula, fauces visible

Class III: soft palate, base of uvula visible

Class IV: hard palate only visible

In less emergent scenarios, the Mallampati score is commonly used to assess jaw movement and mouth space. **■ Figure 4-2** illustrates the Mallampati score. This assessment is performed with a cooperative patient in the sitting position. Therefore, the Mallampati score is of limited utility in trauma. Several other scoring systems have been used to predict difficult airways (e.g., the MACOCHA score), but none have been specifically validated in trauma patients.

Hypoxemic and hypotensive physiology are associated with rapid development of apnea and inability to maintain an open airway. In these situations, a high risk of precipitous cardiorespiratory deterioration is present during airway management and positive-pressure ventilation. **Pre-intubation fluid resuscitation, oxygenation, monitoring, and preparation of vasopressors are important to reduce the risk of lethal complications.**

ADJUNCTS TO ASSESSMENT

Physiological monitoring by pulse oximetry and end-tidal capnography is of critical importance in airway management.

PULSE OXIMETRY

Pulse oximetry provides near-real-time information. However, it has important limitations. There is a 30- to 60-second delay (potentially longer in shock) between a change in alveolar oxygen levels and a change at the oximeter. Residual oxygen in the lungs may maintain blood oxygenation for several minutes even if complete airway obstruction is present. Thus, a decrease in SpO_2 is a late sign of airway obstruction, especially when supplemental oxygen has been administered. **Inability to obtain oximetry readings may result from either severe hypoxia or hypoperfusion (e.g., shock or hypothermia states).** The absence of a reading indicates the need for investigation and treatment of both possibilities. **Most pulse oximeters will read falsely high in cases of CO poisoning.** Special CO pulse oximeters are available in some treatment areas.

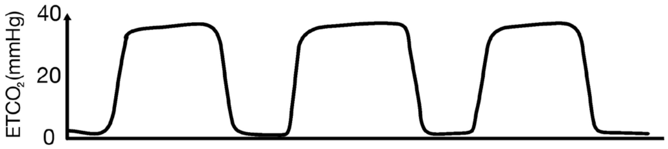
CAPNOGRAPHY

Capnography measures the presence of exhaled CO_2 and provides valuable information regarding airway patency. Waveform capnography, if available, is also useful for nonintubated patients (e.g., during face mask and laryngeal mask ventilation, as well as spontaneous ventilation with supplemental oxygen). The absence of exhaled CO_2 indicates lack of ventilation and airway obstruction unless proven otherwise (including in cardiac arrest). **Capnographic detection of sustained exhaled CO2 is the best practical indicator to confirm successful intubation. Sustained detection is defined as CO_2 present on at least seven breaths.** An alternative method of ventilation is employed if exhaled CO_2 confirmation is not achieved.

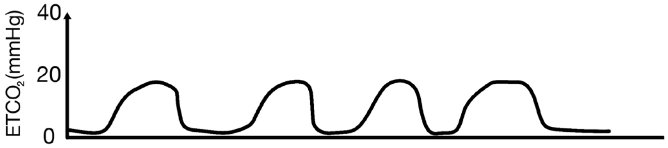
If appropriate equipment is available, end-tidal CO_2 ($ETCO_2$) numerical values may be useful for assessing minute ventilation. However, this assessment is accurate only in a sealed airway (e.g., laryngeal mask or subglottic airway) with a normal waveform as illustrated in **■ Figure 4-3A**. $ETCO_2$ values may assist in management of elevated intracranial pressure (ICP; discussed in Special Population Considerations later in this chapter). A low $ETCO_2$ may be an indication of low cardiac output with paradoxically elevated $PaCO_2$ potentially present. **■ Figure 4-3** illustrates several $ETCO_2$ waveforms.

■ Figure 4-3: Common Capnography Waveforms.
A. Normal capnograph where $ETCO_2$ can accurately estimate $PaCO_2$. **B.** Partial upper airway obstruction or hypoventilation. Smaller, rounded waves are seen if tidal volume is low. Measured $ETCO_2$ will underestimate $PaCO_2$. **C.** Bronchospasm. 'Shark-fin' waves are seen in bronchospasm and some other situations. The measured $ETCO_2$ will underestimate the $PaCO_2$. **D.** Esophageal intubation. CO_2 may be returned from the stomach initially but will diminish over time. In successful endotracheal intubation, exhaled CO_2 is sustained. This is defined as CO_2 being adequately detected on a minimum of seven breaths. This example shows a higher level of CO_2 than is often seen in esophageal intubation.

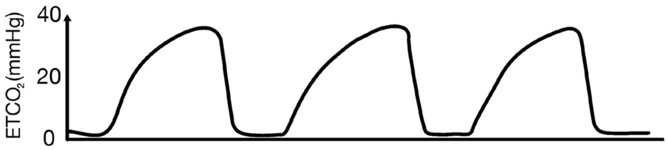
(a) Normal



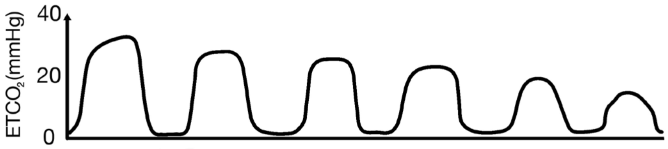
(b) Partial upper airway obstruction/hypoventilation



(c) Bronchospasm



(d) Esophageal intubation



END-TIDAL OXIMETRY

Measurement of exhaled end-tidal oxygen (ETO_2) is utilized in some emergency departments. Reaching an ETO_2 of > 85% may be an indication of adequate preoxygenation prior to attempted intubation.

IMAGING

Due to the urgent need for airway management in trauma, imaging modalities have limited application. A lateral soft-tissue neck radiograph may be useful to assess edema and airway disruption, although sensitivity is limited. CT provides useful information on anatomy and airway injury. However, the time invested to obtain images, the need to lie flat, risks of transport, and loss of access to the airway limits the utility of CT. Ultrasound has been described for airway assessment. However, images are often degraded by air. Specialized training is recommended to obtain useful images and perform accurate interpretation.

INTERVENTIONS/TREATMENTS

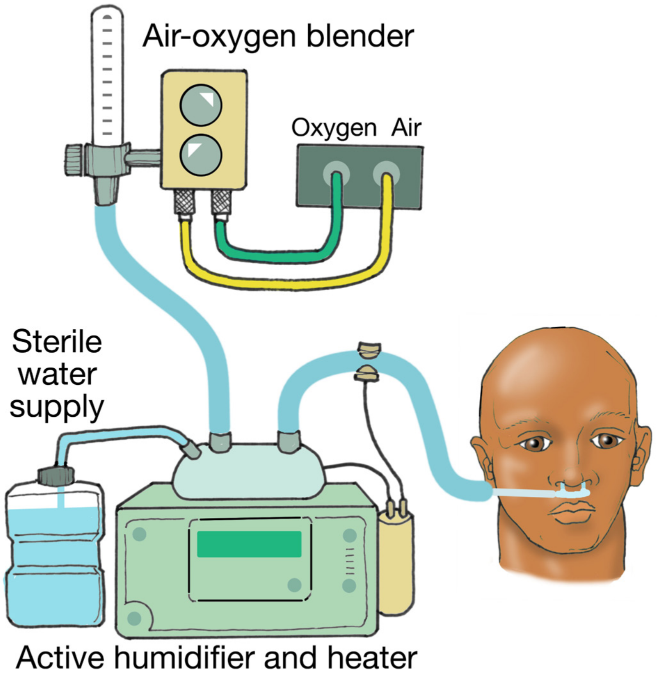
Following control of massive hemorrhage, the clinician opens and maintains the airway. Several injury presentations (e.g., transportation crashes, falls from height, injuries in frail patients, neck gunshot wounds) have the potential of unstable spine injury. Providing simultaneous spinal motion restriction during airway maintenance is important in these clinical scenarios. **If hemorrhagic shock is present, airway maneuvers are performed concurrently with initiation of resuscitation,** as previously mentioned above in the Assessment section (preferentially with blood products; see *Chapter 6, Circulation Assessment and Volume Resuscitation*). Clinicians consider the available resources and scope of practice to select the best intervention to maintain oxygenation and ventilation. Oxygen delivery devices are important adjuncts.

OXYGEN DELIVERY DEVICES

Prolonged hypoxia may lead to arrhythmias, hemodynamic decompensation, hypoxic brain injury, and death. **Therefore, preventing hypoxia is crucial. When available, oxygen is administered to trauma patients with abnormal oxygen saturations (i.e., <94%), those with airway obstruction, or those in whom oxygenation cannot be measured (due to a lack of equipment or poor perfusion).** A target SpO_2 of 94%–98% is generally appropriate. Initiating treatment with a reservoir mask (nonrebreather mask) at a flow rate of 15 L/min is reasonable.

Other oxygen delivery devices include standard oxygen masks and nasal cannula, which deliver a lower fraction of inspired oxygen (FiO_2) than reservoir masks. High-flow nasal oxygen (HFNO) can deliver up to 100% O_2. **■ Figure 4-4** illustrates HFNO. HFNO is contraindicated in severe facial trauma or basal skull fracture. A self-inflating bag-valve mask (BVM) with a one-way positive end-expiratory pressure (PEEP) valve (to prevent room air being inspired through the expiratory port) can provide close to 100% O_2. Noninvasive ventilation may occasionally be useful and can deliver high FiO_2. However, noninvasive techniques increase the risk of aspiration through gastric distension. Invasive definitive airway methods may be more appropriate for severely hypoxemic trauma patients.

■ Figure 4-4: High-Flow Nasal Oxygen (HFNO) Equipment. HFNO delivers humidified and warmed oxygen at flow rates that exceed peak inspiratory flow (e.g., 60 L/min). The warmth, humification, and wider nasal cannula allow these flow rates to be tolerated.



BASIC AIRWAY MANEUVERS

These interventions have relatively rapid application. Airway patency is continuously assessed. Continuous capnography is useful when available.

LATERAL POSITIONING

Placing the patient in a left-side-down position is a highly effective and noninvasive technique in airway management. It may be particularly useful in mass casualty scenarios or resource-limited settings where clinical resources are overwhelmed. In these settings, unconscious patients may be placed in the left lateral position if continuous one-to-one monitoring is not feasible. Lateral positioning can assist with management of airway obstruction by blood, vomitus, or other foreign material. In these overwhelming clinical scenarios, spinal movement is minimized as much as possible (maintaining alignment with collars, boards, log roll technique), while airway management takes precedence.

SUCTION AND REMOVAL OF FOREIGN MATERIAL

A rigid suction catheter can clear liquid from the pharynx. However, larger material may block the catheter. Specialized, larger-bore rigid suction catheters have been designed for airway management. These can aspirate larger particulate material. Suction catheters are used under direct vision to avoid causing oropharyngeal injury. Narrow, flexible suction catheters are ideal for aspiration of the lumen of airway devices. However, these are less suitable for massive amounts of material.

Massive amounts of oropharyngeal matter can be managed by placing the patient in the left lateral position (as mentioned earlier), suctioning, and manual/digital removal of the material. Visualization with a laryngoscope and placement of a suction catheter in the upper esophagus can be useful in managing vomitus. Angled forceps (e.g., Magill or Boedeker) can be used with direct visualization to remove solid objects and material.

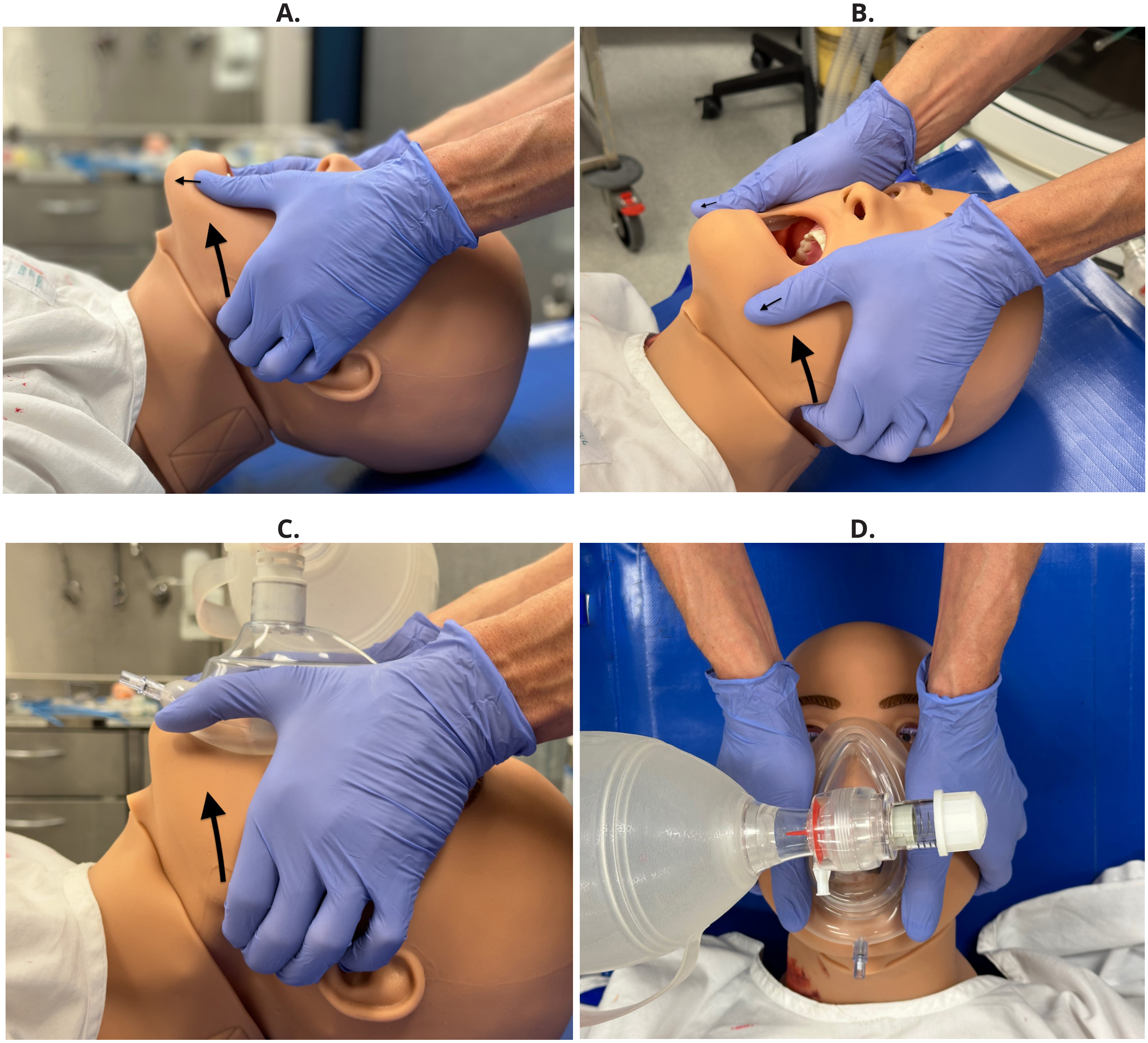
JAW THRUST

Jaw thrust involves moving the mandible anteriorly to displace oropharyngeal soft tissues and create an air passage. When combined with clearance of oropharyngeal material and mask ventilation, the jaw thrust may maintain an open airway until further expertise and equipment arrive to the bedside. The maneuver may be uncomfortable for the patient and may not be tolerated by semiconscious patients. Reduced force may provide adequate airway patency in such situations. The *vise grip* technique is effective and can be applied with or without mask ventilation. **■ Figure 4-6** illustrates the jaw thrust maneuver and vise grip. An isolated chin lift is less effective and may produce more spinal movement. Hand position may be altered to avoid facial fractures and other injuries while maintaining anterior mandible displacement.

MASK VENTILATION

Positive pressure ventilation can be applied with a mask connected to a self-inflating bag (i.e., BVM), anesthesia circuit, or mechanical ventilator. However, positive pressure alone does not overcome airway obstruction. A jaw thrust with an oropharyngeal or nasopharyngeal airway (see below) is often employed. The mask can be secured with one or two hands. A two-handed vise grip, as illustrated in **■ Figure 4-5**, is most effective when adequate personnel are present. Jaw thrust, oropharyngeal airways, and nasopharyngeal airways are very effective in combination with mask ventilation.

■ **Figure 4-5: Jaw Thrust and "Vise Grip".** (Oxygen mask and oropharyngeal airway have been removed for illustrative purposes) **A and B, Jaw Thrust:** The clinician's thenar eminences rest on the patient's maxilla. The fingers are placed behind the angle of the mandible bilaterally. The mandible is pulled anteriorly. The thumbs can be used to open the mouth. **C and D, Vise Grip and Mask Ventilation:** The mask is held with the thenar eminences and the mandible pulled anteriorly into the mask. Wrist movements are used to optimize the seal of the mask. A second clinician ventilates. It is helpful for the clinician's elbow to be extended either by lowering the bed or providing a step for the clinician.



UPPER AIRWAY DEVICES

Various devices are available that are intended to maintain airway patency above the vocal cords. They are relatively quick to insert and are less invasive compared to subglottic devices.

OROPHARYNGEAL AIRWAYS

These minimally invasive devices extend to behind the tongue and are sized from the incisors to the angle of the jaw. **Oropharyngeal airways stimulate a gag response.** To prevent emesis, they are removed if gagging occurs.

NASOPHARYNGEAL AIRWAYS

These devices are inserted into the nose and extend into the oropharynx at the base of the tongue. They are sized by measuring from the nose to the tragus of the ear. There is a risk of bleeding during insertion, so lubrication and gentle placement are important. A nasopharyngeal airway is not advanced against significant resistance. They are less stimulating of a gag response than oropharyngeal airways. **Nasopharyngeal airways are contraindicated in facial and basilar skull fractures.**

SUPRAGLOTTIC AIRWAYS

Supraglottic airways are designed to maintain airway patency without passing through the larynx. Thus, they are less invasive than endotracheal tubes. The term *supraglottic airway* may sometimes include oropharyngeal and nasopharyngeal airways but more commonly refers to devices that can be directly connected to a ventilator, such as laryngeal masks, laryngeal tubes, and esophageal-tracheal double-lumen devices. Of these, only the laryngeal mask is discussed in ATLS. Prehospital services in some regions may employ other devices. Familiarization with local prehospital airway techniques is beneficial.

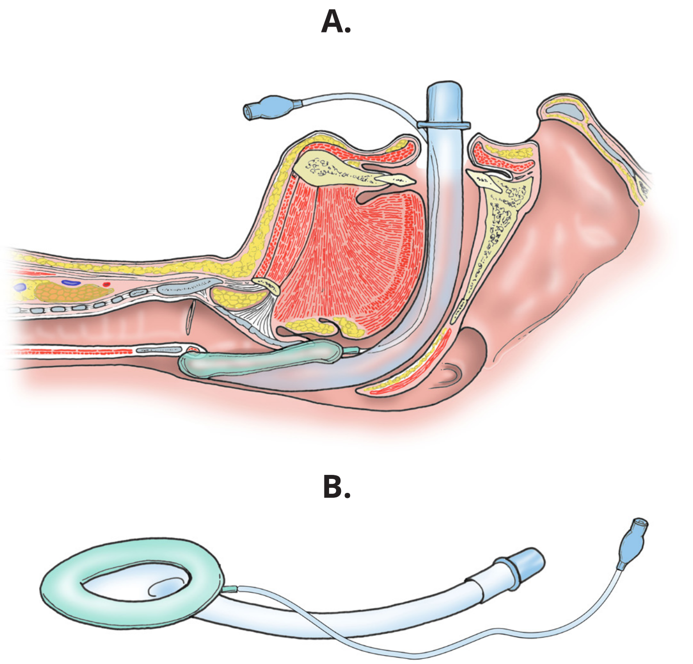
LARYNGEAL MASKS

Laryngeal mask airways (LMAs) are inserted without laryngoscopy. Many different devices exist, and the clinician is encouraged to be familiar with local equipment. LMAs generally provide improved airway patency, more effective positive pressure ventilation, and some protection against regurgitation and aspiration in comparison to oropharyngeal and nasopharyngeal airways with mask ventilation. ■ **Figure 4-6** illustrates an LMA. **As with oropharyngeal airways, laryngeal masks are only tolerated by obtunded or anesthetized patients. Insertion is abandoned if a gag reflex is elicited.**

RAPID-SEQUENCE TRACHEAL INTUBATION

An airway device in the trachea with an inflated cuff distal to the vocal cords is termed a definitive airway. This is usually an oral endotracheal tube but can be a surgical/incisional airway. Despite the term *definitive*, continuous reassessment is performed to maintain the airway. **Tubes can dislodge, obstruct, or leak.** Constant vigilance is critically important. Tracheal intubation establishes a definitive airway. However, the procedure is associated with significant risks. Adequate training, time, and resources are imperative to safe performance. **Intubation generally provides improved ventilation and protection against aspiration as compared to less invasive options. The absolute and immediate indication for intubation is life-threatening hypoxia due to airway obstruction that is not relieved by basic or upper airway maneuvers.**

■ **Figure 4-6: Laryngeal Mask Airway. A.** The LMA is inserted without visualization of the vocal cords. Oriented anteriorly, it creates a seal at the origin of the trachea and is proximal to the vocal cords. The esophagus is posterior. **B.** An LMA. The green area represents the cuff of the LMA which rests at the origin of the trachea.



Large studies show that intubation has higher rates of serious complications than noninvasive airway maneuvers. Therefore, intubation is performed when other measures are, or are likely to be, ineffective. **Except during cardiac arrest, drug-facilitated intubation is performed in trauma scenarios.** Laryngoscopy and intubation without premedication stimulate gag reactions and may cause physiologic responses that increase technical difficulty (e.g., vocal cord spasm), even in profoundly obtunded patients.

Drug-facilitated intubation is performed as a modified RSI technique. In this manual, the terms *RSI* and *modified RSI* are used interchangeably. **The word rapid describes the relatively short time between drug administration and securing the airway; it does not imply a hurried or rushed process.** Even well-rehearsed teams may take 5–10 minutes to prepare and perform a safe RSI.

RISKS OF RSI

RSI involves the administration of drugs which abate respiratory effort. Therefore, **the most significant risk during RSI is loss of the airway and/or respiratory drive.** Once medications are administered, the clinician is committed to providing airway and ventilation, which may be accomplished via successful intubation, rescue laryngeal mask, rescue mask ventilation, or surgical/incisional airway.

A catastrophic complication of attempted intubation is unrecognized misplacement of the endotracheal tube into the esophagus. **Esophageal intubation is fatal unless recognized immediately. Identification of this complication is made rapidly and accurately by lack of sustained exhaled CO_2. Upon diagnosis of failed tracheal intubation, the tube is immediately removed, and ventilation and oxygenation are provided via laryngeal mask or facial mask ventilation.** Improvement in oximetry is critical prior to further intubation attempts. If oxygenation and ventilation cannot be adequately provided, a surgical/incisional airway may be indicated.

Laryngoscopy and intubation can injure the airway. Injury is more common with repeated attempts and can make effective mask or laryngeal mask ventilation impossible. Hence, most guidelines limit the number of attempts at intubation. **All sedative medications used for RSI may induce or worsen hemodynamic derangement.** Doses are reduced compared to elective intubation. **The transition from spontaneous ventilation to positive-pressure ventilation significantly alters hemodynamic physiology with a risk of resultant cardiovascular collapse in hypovolemic patients. Hypovolemic patients are administered fluid resuscitation prior to RSI.** Vasopressors are commonly administered presumptively during RSI to offset vasodilation induced by sedative agents.

DECISION TO PERFORM AND TIMING OF RSI

RSI utilizes time and resources, which may detract from other treatment priorities. RSI is often deferred until further resuscitation is performed and/or more resources are available. ■ **Table 4-2** lists several factors to consider regarding RSI.

Some patients arrive with a functioning supraglottic airway inserted by prehospital clinicians. The decision to remove the prehospital device and perform intubation follows the same principals listed above. **If oxygenation or ventilation are inadequate, assessment and revision or provision of an alternate airway device is a priority. However, if oxygenation and ventilation are adequate, the prehospital airway may be continued with replacement temporarily deferred until optimal personnel and equipment are available for more controlled intubation.**

EQUIPMENT FOR RSI

Successful RSI utilizes specialized equipment for safe performance of the procedure and for airway rescue maneuvers.

Endotracheal Tubes

Various sizes of endotracheal tubes are available for both adult and pediatric use (e.g., 7-9 mm internal diameter for adults). For trauma intubations, cuffed tubes are appropriate in all age groups including small children.

Laryngoscopes

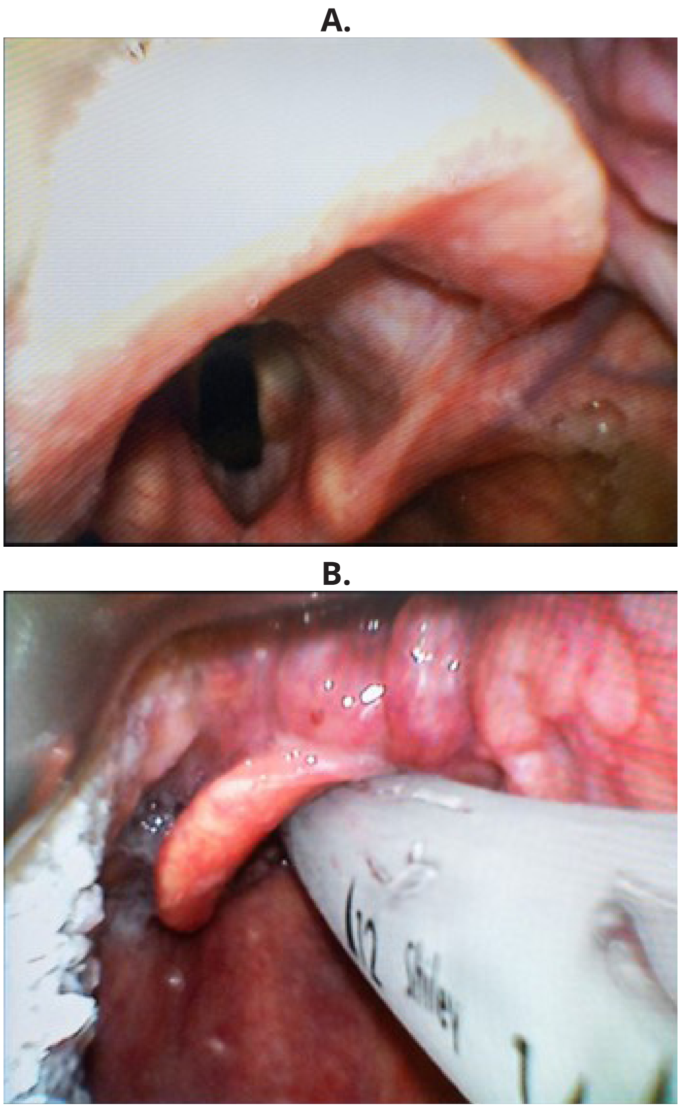
Immediate availability of least two functional laryngoscopes (i.e., one used and one as backup) is optimal. There are two types in common use. Direct laryngoscopes (DLs) are intended for visualizing the larynx with the unaided eye. The Macintosh (curved blade) is the most common. Straight blades (e.g., Miller) are sometimes beneficial for intubation of small children with a slightly modified technique. Several specialized DLs exist for various purposes and techniques.

Video laryngoscopes (VLs) have a camera and screen (or, less commonly, an eyepiece) and improve intubation success rates. VLs are optimal for trauma intubations. It is helpful for the screen to be visible to the team. ■ **Figure 4-7** illustrates intubation via VL. Clinicians less experienced at intubation may find VL easier with a blade similar in shape to a Macintosh direct laryngoscope blade. ■ **Figure 4-8** illustrates different laryngoscope blades and an endotracheal tube with stylet. Extended-angle VL blades are effective but are difficult to use for those without additional training.

■ **Table 4-2: Factors to Consider in Timing of RSI.**

Factors toward *immediate* RSI	Factors toward *delaying or deferring* RSI
Inability to oxygenate via mask or supraglottic airway (absolute indication), or difficulty maintaining ventilation with these methods Appropriate resuscitation and adequate hemodynamic status Inability to maintain airway patency due to airway bleeding, regurgitation, or emesis Lack of or prolonged delay until availability of airway specialist Definitive airway indicated for safe transfer	Well-functioning upper airway device or patient maintaining airway spontaneously Hypotension or hemodynamic abnormality Inadequate intubation experience Potential or suspected difficult airway and anticipated rapid arrival of expert assistance More urgent clinical priorities Inadequate staff available to assist Rapid availability of airway specialist Multi-casualty scenario

■ **Figure 4-7: Video Laryngoscope Screens. A.** Larynx and vocal cords before intubation. **B.** Endotracheal tube (ETT) passing through vocal cords after intubation.



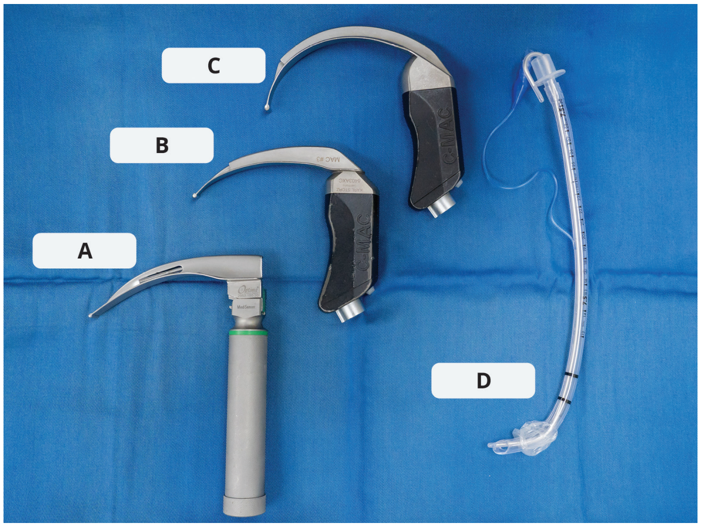
Eschmann Endotracheal Tube Introducer/Gum-Elastic Bougie

Commonly called a *bougie*, this device may assist challenging intubations. It is placed either blindly or via laryngoscopy. An angled tip facilitates anterior passage through the oropharynx and larynx. ■ **Figure 4-9B** illustrates a bougie. An endotracheal tube is inserted over the bougie into the trachea.

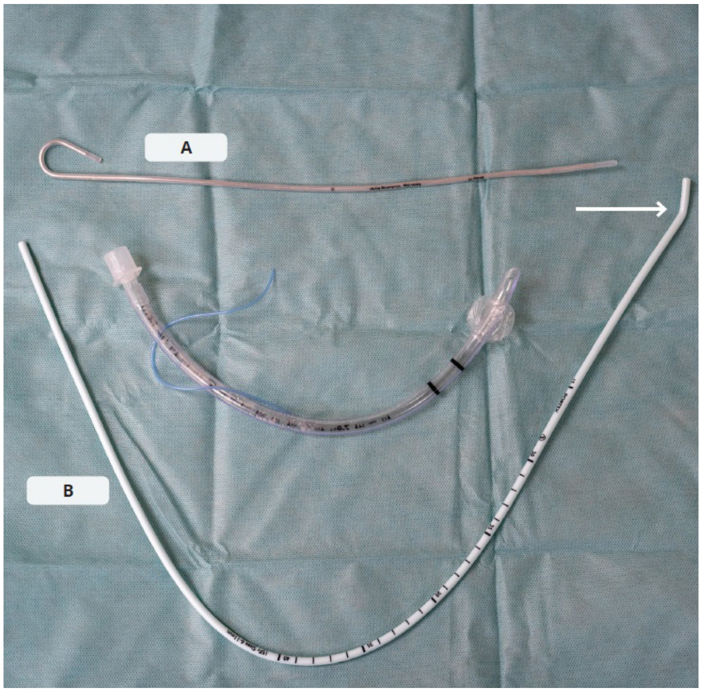
Malleable Stylet

This device assists intubation by maintaining the flexible endotracheal tube in a desired shape, typically straight with a bend at the cuff. ■ **Figures 4-8D and 4-9A** illustrate stylets.

■ **Figure 4-8: Laryngoscope Blades and Stylet in Endotracheal Tube.** The shape of the direct laryngoscope (DL) with Macintosh blade (**A**) and video laryngoscope (VL) standard-geometry blade (**B**) are very similar. The same intubation technique is used with both devices. The VL may be used as a direct laryngoscope in the event of camera failure. The extended-angle VL blade (**C**) uses a different technique with additional training. The VL blades are connected via a cable to the screen. **D.** A stylet inserted into a shaped endotracheal tube with a bend at the cuff.



■ **Figure 4-9: Bougie and Malleable Stylet. A.** Malleable stylet (also illustrated in ■ **Figure 4-8D**). **B.** Bougie. The arrow points at the angulated tip, an important feature of the device. (The bend in the middle of the bougie is the result of packaging. It is not an intended feature.) When using a bougie, a 90-degree anticlockwise rotation of the endotracheal tube can help the tip slide over the arytenoids if the tube becomes wedged at the larynx.



Mechanical Ventilator

While it is possible to ventilate and oxygenate an intubated patient manually with a self-inflating bag or anesthetic circuit, a mechanical ventilator is helpful. The ventilator protects against hypo- and hyperventilation and against clinician fatigue and loss of focus. Examples of initial ventilator settings are discussed later.

MEDICATIONS FOR RSI

Medications for RSI can be organized into three broad categories:

- Sedative and anesthetic agents
- Neuromuscular blockers
- Vasopressor and inotropic agents

Common medications and doses are listed in ■ **Table 4-3**, although other agents may be reasonable based on clinician experience.

■ Table 4-3: RSI Medications and Potential Dosing.

Medication	Dose	Comments
Sedative and anesthetic agents		
Ketamine (sedation)	0.5 mg/kg, repeat if necessary	May induce airway/respiratory collapse
Ketamine (RSI)	0.5-2 mg/kg	Can cause or exacerbate hypotension and shock–dose reduction in shock
Etomidate (RSI)	0.2-0.3 mg/kg	
Propofol (RSI)	Dose determined by an experienced clinician	Can cause or exacerbate hypotension and shock–dose reductions in shock, sometimes up to 90%
Thiopentone (RSI)		
Midazolam (RSI)		
Fentanyl (sedation RSI)	0.5 - 1 mcg/kg	
Medication	**Dose**	**Comments**
Neuromuscular blocking drugs		
Rocuronium	0.6-1.2 mg/kg	Will prevent patient from maintaining spontaneous, unassisted open airway
Suxamethonium (succinylcholine)	1 mg/kg	
Medication	**Dose**	**Comments**
Vasopressors and inotropes		
Metaraminol	0.5-1 mg (or 10 mcg/kg) boluses	
Phenylephrine	50 mcg (or 1 mcg/kg) boluses	
Ephedrine	6 mg (or 0.5 mg/kg) boluses	
Epinephrine (adrenaline)	10-50 mcg (or 1-5 mcg/kg) boluses 0.05 - 2 mcg/kg/min infusion	Depending on severity of hypotension; use higher doses with caution
Norepinephrine (noradrenaline)	0.1-1 mcg/kg/min infusion	Titrated to target blood pressure. For peripheral administration, a dilute solution (e.g., 20 mcg/ml) is used through a reliable access point

Sedatives and Anesthetic Agents

These agents render the patient sedated or unconscious. Opioids are included in this category. Due to altered pharmacology, adverse hemodynamic effects can be magnified in a patient with hypovolemia despite using doses considered safe in nonemergent scenarios. Thus, **all agents have the potential to produce significant hypotension.**

Several medication options are reasonable. **Ketamine and etomidate are selected by many clinicians and are recommended in authoritative guidelines.** These drugs produce relatively fewer hemodynamic alterations. Ketamine results in dissociation such that patients often retain spontaneous eye-opening but lose awareness and purposeful response. While ketamine can cause or exacerbate hypotension, it is more commonly associated with tachycardia with mild hypertension. Potential raised intracranial and pulmonary arterial pressures are likely of less clinical significance than originally proposed. Studies regarding etomidate adrenal suppression support low clinical significance following a single dose.

Benzodiazepines and opioids are commonly used. However, the risk of hypotension with these drugs is significant. Fentanyl reduces the hypertensive and increased intracranial pressure responses that occur with intubation. Therefore, it may be useful in cases of isolated head injury. Opioids may cause hypotension, especially in hypovolemic patients.

Propofol and thiopentone are anesthetic agents and produce significant hypotension with induction doses. They are not frequently utilized in RSI unless the clinician has extensive experience, and the patient is not hypovolemic or at risk for hemorrhagic shock. When used, the usual doses are significantly reduced.

Maintenance sedation is administered for all patients post-intubation. Ketamine, benzodiazepines, propofol, and opioids are all commonly used, either alone or in combination, as infusions or as intermittent boluses.

Neuromuscular Blocking Drugs (NMBDs)

NMBDs cause muscle paralysis at the neuromuscular junction and facilitate laryngoscopy and intubation. Rapidly acting agents are used in RSI to minimize the time between sedation and intubation. Two appropriate agents are suxamethonium (succinylcholine) and rocuronium. Suxamethonium produces muscular relaxation in approximately 45–60 seconds. The onset is characterized by muscular fasciculations. Side effects include hyperkalemia, increased muscular oxygen extraction, and raised intraocular pressure. Hyperkalemia can be severe, even fatal, in patients with high amounts of denervated or necrotic tissue (e.g., more than 24 hours post extensive burns, prolonged immobilization prior to medical care, or spinal injury). Suxamethonium is usually metabolized in 3–5 minutes.

Rocuronium is a nondepolarizing agent. If used at a dose of at least 1.2 mg/kg, it has fewer side effects while providing equivalent intubating conditions to suxamethonium. A reversal agent (sugammadex) is available but is not useful in the context of an ATLS intubation, as waking the patient to restore the airway is not a common option.

Vasopressor and Inotropic Agents

Vasopressors are included in discussion of RSI, as they are used to counteract hypotension induced by RSI medications and positive-pressure ventilation. Agents include metaraminol, phenylephrine, ephedrine, and epinephrine (adrenaline). The specific medications and their availability vary by region. Although fluid and blood are the first treatment for hypotension in the injured patient, vasopressors are useful in treating vasodilation produced by sedatives and anesthetics.

PREPARATION FOR RSI

Checklists and Other Cognitive Aids

Checklists enhance performance and outcomes in medicine and other high-demand industries. **Pre- and post-intubation checklists help ensure that important tasks have not been overlooked and that all members of the team understand the process and priorities (shared mental model).** Checklists are extensively used by experienced airway and trauma management teams. A checklist is beneficial before and after ATLS RSI procedures. Several versions are available. ■ **Figure 4-10** illustrates pre- and post-intubation checklists.

In addition to checklists, airway management teams may utilize other cognitive aids. ■ **Figure 4-11** is an example of a flow diagram that may assist teams in adhering to procedures and in making decisions in complex and stressful situations. Task cards and role stickers clarify individual team members' responsibilities and allow greater autonomy.

Equipment Considerations

A consistent, well-organized equipment layout ensures that vital items can be located quickly. This can be facilitated by using a layout template.

Teamwork

A well-functioning team is important when performing complex procedures such as RSI. A single clinician cannot optimally and simultaneously lead the team and perform intubation. They cannot maintain full situational awareness while performing this complex task. The team leader role is performed by or transitioned to another clinician. Another team member is allocated to monitor vital signs and alert the team to significant changes. Team members are empowered to speak if they observe or have suspicion of a complication or developing problem. A high-functioning team leader will actively encourage communication. The leader is encouraged to request additional personnel, if available, prior to intubation. A shared mental model and awareness are developed through briefing (including plans for intubation failure) and a shared VL screen.

■ **Figure 4-10: Pre- and Post-Intubation Checklist.** Several other checklists are available online and elsewhere.

Checklist: Pre- & Post-Intubation

Pre-Intubation

Optimization

- ○ Physiological state assessed
- ○ Intravenous/Intraosseous access x2
- ○ Resuscitation sufficient
- ○ Pre-oxygenation optimal
- ○ Apneic oxygen considered

Patient Position

- ○ C-spine protection
- ○ Optimized

Monitoring

- ○ Capnography
- ○ Electrocardiogram
- ○ Pulse oximetry
- ○ Blood pressure on 1-minute cycle

Equipment

- ○ Suction x2 (function checked)
- ○ Laryngoscope x2 (function checked)
- ○ Endotracheal tube x2 (cuffs checked)
- ○ Bougie/Stylet
- ○ Syringe
- ○ Bag-valve mask with PEEP valve
- ○ Oropharyngeal airway
- ○ Nasopharyngeal airways
- ○ Laryngeal mask
- ○ Surgical airway kit
- ○ Sufficient oxygen; turned on

Drugs

- ○ Induction agent(s)
- ○ Neuromuscular blocking drug
- ○ Vasopressor(s)/Inotrope(s)
- ○ Post-intubation sedation

Team Briefing

- ○ Roles allocated
- ○ Intubation plan
- ○ Failed intubation plan
- ○ Surgical airway plan
- ○ Physiological deterioration plan (cardiovascular and respiratory)

Post-Intubation

Airway

- ○ Sustained exhaled CO_2
- ○ Bilateral air entry
- ○ Depth at teeth documented
- ○ Tube secured
- ○ Cuff pressure checked

Breathing

- ○ Reassessed
- ○ Safe, appropriate ventilation; alarms set
- ○ Chest x-ray arranged
- ○ Blood gas checked
- ○ Further paralysis available

Circulation

- ○ Reassessed; resuscitation continued
- ○ Vasopressors and fluids available

Disability

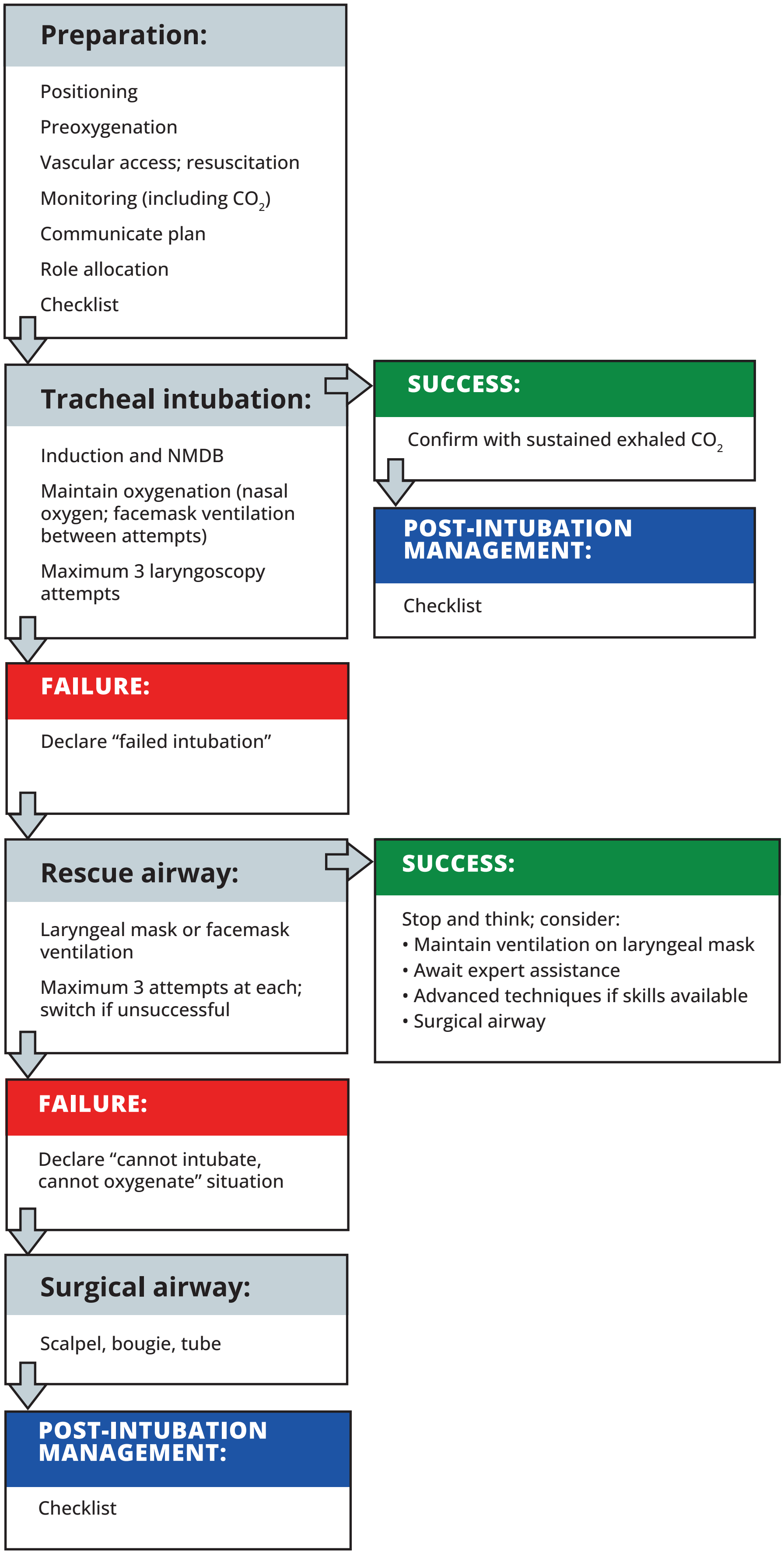
- ○ Sedation established
- ○ Head-up position (if able)
- ○ TBI optimization (if applicable)
- ○ C-spine collar reapplied (if appliable)

Environment

- ○ Back-up BVM available
- ○ Oxygen supply adequate
- ○ Gastric tube

Notes:

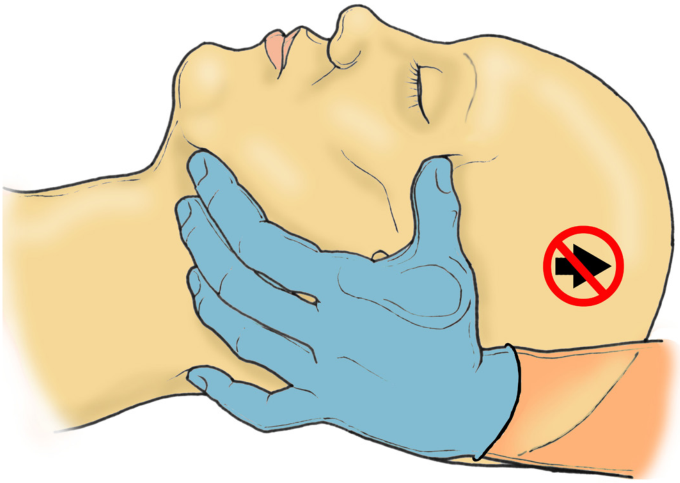
■ **Figure 4-11: Flow Diagram Summarizing Modified Rapid Sequence Intubation (RSI).**


Preparation:
Positioning
Preoxygenation
Vascular access; resuscitation
Monitoring (including CO_2)
Communicate plan
Role allocation
Checklist
Tracheal intubation:
Induction and NMDB
Maintain oxygenation (nasal oxygen; facemask ventilation between attempts)
Maximum 3 laryngoscopy attempts
SUCCESS:
Confirm with sustained exhaled CO_2
POST-INTUBATION MANAGEMENT:
Checklist
FAILURE:
Declare “failed intubation”
Rescue airway:
Laryngeal mask or facemask ventilation
Maximum 3 attempts at each; switch if unsuccessful
SUCCESS:
Stop and think; consider:
• Maintain ventilation on laryngeal mask
• Await expert assistance
• Advanced techniques if skills available
• Surgical airway
FAILURE:
Declare “cannot intubate, cannot oxygenate” situation
Surgical airway:
Scalpel, bougie, tube
POST-INTUBATION MANAGEMENT:
Checklist

Protection of the Cervical Spine

Neck movement is minimized in the blunt trauma patient, although there is some controversy regarding the best method. Manual inline stabilization of the head is routinely performed for blunt trauma in many systems. As illustrated in ■ **Figure 4-12**, **the head and neck are stabilized as a single unit to oppose the lifting force of laryngoscopy. Traction is not applied.** Use of a VL and gentle technique may minimize neck movement. In immediately life-threatening scenarios, oxygenation and ventilation take primacy over cervical spine stabilization. The clinician may prioritize airway management (being as gentle as possible) in these scenarios. Although there are cases where small amounts of gentle neck movement have exacerbated spinal injury, thankfully, this is rare.

■ **Figure 4-12: Manual Inline Stabilization (MILS).** MILS can be performed either from the side or head, as shown. The choice is based on ergonomics and individual preference. The clinician performing MILS holds the head still against the force of laryngoscopy, being careful not to apply traction.



Optimizing Intubation Attempts

The first attempt at intubation is the optimal attempt. Repeated attempts can cause airway trauma and other complications and are associated with increased mortality. A common mantra is *"make the first attempt the best attempt."* The following are associated with increased intubation success:

- Trauma intubation is performed by an experienced clinician whenever possible
- Video laryngoscopy is used, ideally with a screen visible to the whole team
- A bougie or stylet is used
- The patient is positioned as optimally as possible

Cricoid Pressure

This technique attempts to compress the esophagus with the larynx to reduce the risk of regurgitation. However, effectiveness has not been demonstrated. The maneuver may impair intubation and effective laryngeal mask placement. Therefore, routine application of cricoid pressure is not performed unless requested by an airway management expert in an individual case.

Positioning

The patient is positioned as far to the head of the bed as possible. A reverse Trendelenburg tilt of 20–30 degrees is advantageous. Greater degrees of torso elevation are helpful in obese and pregnant patients. Neck extension may be utilized when a cervical spine injury is not potentially present.

Preoxygenation

Preoxygenation is fundamental to safe RSI and is considered before changing or manipulating an airway device. The goal of preoxygenation is to displace nitrogen from the lungs, replacing it with oxygen. Hence, this process is termed *denitrogenation*. Preoxygenation creates an intrapulmonary oxygen reservoir that can sustain oxygenation during apnea, extending the time for safe intubation.

In effective preoxygenation, the volume of inhaled nitrogen-containing room air is minimized. PEEP may aid in preoxygenation. Preoxygenation is typically performed via BVM with attached PEEP valve, if available. Alternatively, noninvasive ventilation or HFNO are used for preoxygenation, with the caveat that noninvasive ventilation may predispose the patient to gastric distension and emesis. Use of reservoir masks is less effective, as the oxygen flow rate is insufficient to prevent inspiration of room air unless a high-flow (60 L/min) regulator is used.

If end-tidal oxygen (ETO_2) monitoring is available, preoxygenation is continued until ETO_2 reaches 85%. Otherwise, preoxygenation continues for several minutes if possible. However, adequate time may not be available in some critical scenarios. SpO_2 readings are not an indicator of adequate preoxygenation. Normal pulse oximetry readings occur before all nitrogen is displaced from the lungs. Preoxygenation is performed with the patient semirecumbent (head up). If this position is not possible, the entire bed can be tilted in reverse Trendelenburg position to elevate the head.

Patients who are agitated or otherwise intolerant of preoxygenation may benefit from mild sedation administered by experienced clinicians. This is sometimes referred to as *delayed-sequence intubation*. Titrated ketamine is effective for delayed-sequence intubation, although other agents may be appropriate as well. The clinician must be fully prepared to initiate airway and respiratory support when administering sedatives to a critically ill patient, as responses can be unpredictable.

Apneic Oxygenation

Apneic oxygenation involves providing oxygen to the patient during the apneic phases of intubation, such as during laryngoscopy. Even though there is no active respiratory effort, hypoxia may be delayed by passive administration of oxygen via either standard nasal cannula (flow can be increased once RSI is initiated) or HFNO. During RSI, gentle mask ventilation is advantageous. Mask ventilation is continued until intubation and resumed between intubation attempts.

RSI PROCEDURE

There are several safe methods to perform RSI; one technique supported by guidelines is described here. This description complements the flow diagram illustrated in **■ Figure 4-11.**

After the clinician performs an assessment, initiates control of exsanguinating external bleeding, administers resuscitation, and makes the decision to intubate, the patient is appropriately positioned. Preoxygenation is initiated as early as possible. Monitors are applied, including capnography if available. Automatic blood pressure devices are set to cycle every 1–2 minutes, or a team member is assigned to obtain manual blood pressure readings frequently. Concurrently, equipment, fluids, and drugs are prepared, roles are allocated, and the team is briefed. A checklist, such as illustrated in **■ Figure 4-10**, is completed immediately prior to administering the RSI drugs.

RSI commences with the administration of a sedative and/or induction agent immediately followed by a muscle relaxant. A bolus of vasopressor may be appropriate at the same time. Once spontaneous respiratory effort stops, mask ventilation is initiated. Mask ventilation is critically valuable when hypoxia is present or likely (e.g., respiratory failure, obesity) or where hypercapnia is to be avoided (e.g., TBI, metabolic acidosis, right heart failure). Nasal prong oxygen flow is increased to 15 L/min during the apneic period to reduce the risk of hypoxia.

Approximately 60 seconds after administration of RSI medications, laryngoscopy with intubation is attempted. The clinician visualizes the tongue with the laryngoscope and follows the tongue until the epiglottis is visualized. The tip of the epiglottis is lifted to reveal the larynx. Inability to visualize the larynx can be managed by withdrawing the laryngoscope partially (the tip may be in the esophagus) and having an assistant manually displace the larynx to the right, posteriorly, and cephalad. This maneuver is sometimes known as *external laryngeal manipulation* or *BURP* (backward, upward, rightward pressure).

If the initial attempt is unsuccessful, the team is alerted and mask ventilation with an oropharyngeal airway or laryngeal mask is performed. **Further attempts at intubation are unlikely to be successful unless a mitigating factor is changed (e.g., patient position, equipment, removal of obstructing material, or operator). Additional intubation attempts include a modification.** Intubation attempts are limited to three per operator (with one further attempt by a more experienced operator). However, fewer attempts may be appropriate, as every attempt increases the chance of edema and airway obstruction. Ventilation via BVM or laryngeal mask is critical between intubation attempts. Inability to ventilate via BVM, laryngeal mask, or intubation (with a maximum of three attempts at each) is an indication for a surgical/incisional airway.

Confirmation of Intubation and Post-intubation Assessment

As mentioned earlier, a catastrophic potential complication of RSI is unrecognized esophageal intubation. Therefore, confirmation of tube location in the trachea and prompt recognition of dislodgement are critical. **Appropriate endotracheal tube position is confirmed by visualization of sustained exhaled carbon dioxide, which is defined as being present for at least seven breaths.** Even in cardiac arrest, carbon dioxide is detectable. Visualization of the tube passing between the cords is surprisingly unreliable. Clinical examination (breath sounds, chest rise, SpO_2) is also unreliable for confirmation of tracheal tube location.

Adequacy of ventilation is reassessed. Breath sounds are auscultated, and chest rise is visualized to evaluate for endobronchial intubation (right or left mainstem) or exacerbated pneumothorax. The tracheal tube is secured with a tie or other device. The tube depth at the teeth or gums is recorded. A chest radiograph is performed to exclude pneumothorax and to confirm that the tube tip is not too distal, resulting in endobronchial (mainstem) intubation. Chest radiography is unable to exclude esophageal intubation.

SURGICAL/INCISIONAL AIRWAY

A surgical/incisional airway is indicated if oxygenation is unsuccessful via face mask, laryngeal mask or intubation, a situation termed *cannot intubate, cannot ventilate* or *cannot intubate, cannot oxygenate.* While a surgical (or incisional) airway is not a technique to be performed casually, it may be a lifesaving procedure. Training, practice, and teamwork can provide the clinician with the confidence to perform this procedure promptly and effectively.

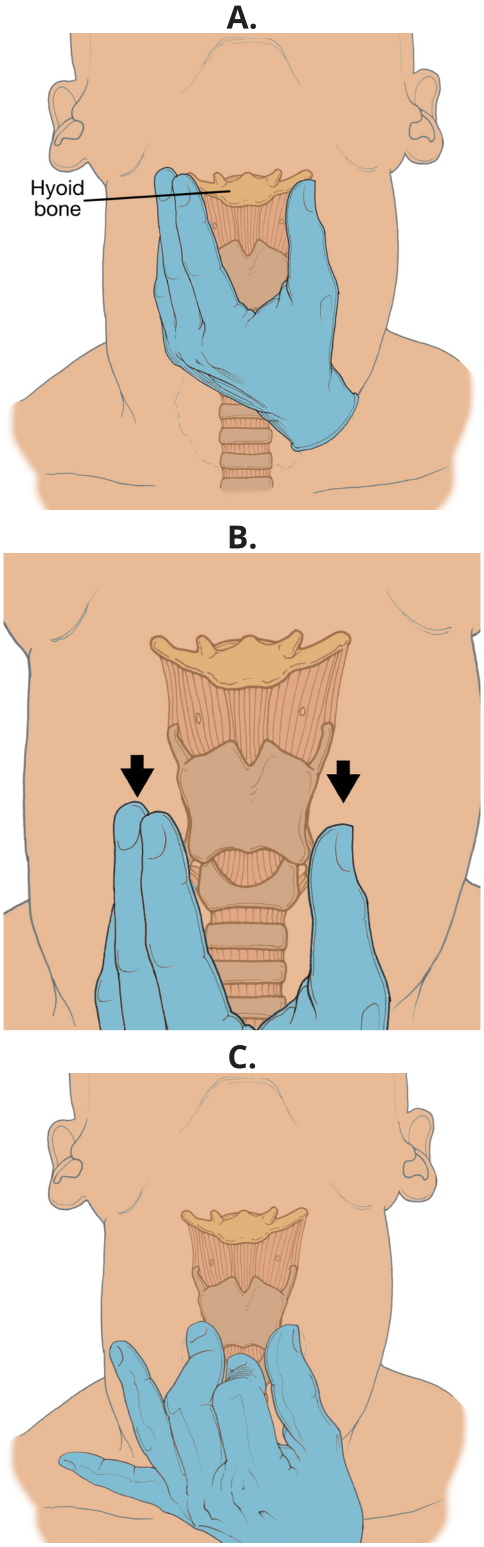
Communication of the *cannot intubate, cannot oxygenate* situation by any team member is important; delay of a surgical/incisional airway can be catastrophic. After the first unsuccessful attempt at intubation, the surgical/incisional airway equipment is prepared by another team member. **A surgical/incisional airway may be appropriate without attempting any or all other airway maneuvers in severe facial and upper airway injury.**

While several surgical techniques are reasonable, the technique in ATLS was chosen due to simplicity, speed, success rate, and lack of necessary specialized instruments. The minimal equipment are a scalpel (preferably a size 10 or 15 blade) and an endotracheal tube (approximately size 6.0). Larger tubes are more difficult to insert. A bougie may be beneficial and is usually available as part of the intubation equipment. Lubrication of the tube and bougie can be helpful. The neck is positioned as for oral intubation, with spinal motion restricted as best as possible in this emergent situation. The clinician must not be dissuaded by the anticipated significant bleeding and air spray. Once commenced, the procedure must be completed despite obstacles.

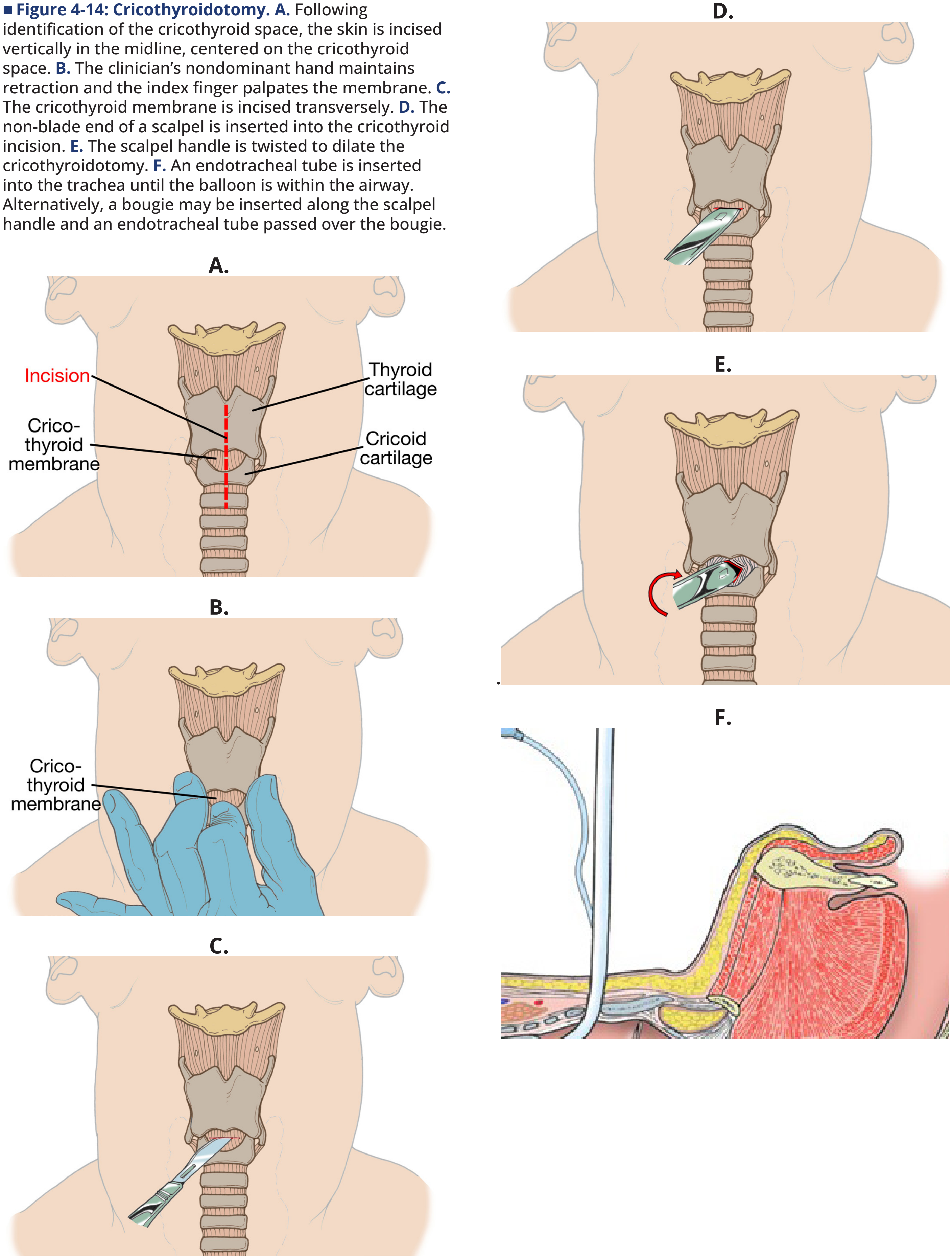
TECHNIQUE

1. An assistant maintains manual cervical motion restriction. The front of the cervical collar is removed (if present).
2. The nondominant hand identifies the thyroid cartilage, spreads and retracts the tissues overlying the cricothyroid space, and stabilizes the larynx. The cricothyroid space is palpated by the nondominant index finger. As illustrated in **■ Figure 4-13**, the *laryngeal handshake* may assist in identification of the cricothyroid space. An assistant may perform retraction if a large amount of tissue is present. The clinician maintains continuous retraction by not releasing the nondominant hand, which may also provide tamponade of bleeding.
3. While maintaining lateral tension on the tissues with the nondominant hand (for skin retraction), a vertical incision is made in the midline from the thyroid cartilage superiorly to the cricoid cartilage inferiorly as illustrated in **■ Figure 4-14**. The vertical incision minimizes potential to encounter larger midline vessels. The incision is of adequate length to facilitate cricothyroid identification: approximately 3–5 cm. The incision may be extended caudad or cephalad as needed until the cricothyroid membrane is palpated.
4. Blunt or sharp dissection is utilized to identify the cricothyroid membrane, which is palpated between the thyroid cartilage and cricoid ring. During dissection, the clinician frequently palpates the underlying structures to maintain midline dissection and avoid injury to the lateral structures of the neck.
5. The cricothyroid membrane is incised transversely. Laceration of the posterior trachea is avoided by using a transverse incisional motion as opposed to an up-and-down sawing motion.
6. The scalpel is removed from the neck. The back handle (non-blade end) of the scalpel is partially inserted into the trachea and rotated several times to dilate the cricothyroidotomy. Utilizing the blunt end of the scalpel handle reduces risk of laceration to the posterior wall of the trachea.
7. Insertion of a fingertip will confirm entry into a hollow, rigid tube. A bougie (if immediately available) may be passed into the trachea while the non-blade end of the scalpel handle is used as a guide.
8. An endotracheal tube is inserted directly (or over the bougie) through the cricothyroidotomy into the trachea. The precise size of the tube is not critical. The tube needs to be small enough for easy insertion and large enough for adequate ventilation. The tube may be exchanged after patient status is improved and an airway expert is present.
9. The tube is advanced only until the balloon is completely within the trachea to avoid mainstem intubation.
10. The endotracheal tube balloon is inflated. The bougie is removed if present. Assisted ventilation is performed. Appropriate location is verified with sustained $ETCO_2$ detection and auscultation of bilateral breath sounds.
11. The tube is secured with sutures to the skin after ensuring a tracheal location without mainstem placement.

■ Figure 4-13: The Laryngeal Handshake. A. The index finger and thumb grasp the top of the larynx at hyoid bone.
B. The fingers and thumb slide inferiorly over the thyroid cartilage. **C.** The middle finger replaces the index finger at the thyroid cartilage cricoid junction. The thumb rests on the cricoid cartilage, with the index finger palpating the cricothyroid membrane.



■ **Figure 4-14: Cricothyroidotomy. A.** Following identification of the cricothyroid space, the skin is incised vertically in the midline, centered on the cricothyroid space. **B.** The clinician's nondominant hand maintains retraction and the index finger palpates the membrane. **C.** The cricothyroid membrane is incised transversely. **D.** The non-blade end of a scalpel is inserted into the cricothyroid incision. **E.** The scalpel handle is twisted to dilate the cricothyroidotomy. **F.** An endotracheal tube is inserted into the trachea until the balloon is within the airway. Alternatively, a bougie may be inserted along the scalpel handle and an endotracheal tube passed over the bougie.


A.
Incision
Thyroid cartilage
Crico-thyroid membrane
Cricoid cartilage
B.
Crico-thyroid membrane
C.
D.
E.
F.

POST-INTUBATION MANAGEMENT

Following intubation, continuous assessment of the airway is indicated throughout the remainder of the trauma initial assessment. ■ **Table 4-4**, lists factors related to post-intubation management.

Frequently, administration of additional sedation is indicated following intubation. Infusions of one or more sedatives are commonly initiated, with doses titrated to a specific sedation level while mitigating potential hypotension. NMBDs have no sedation effect and are administered with additional pain and anxiety relief. NMBDs impair neurological assessment (e.g., movement in response to painful stimulus). However, pupillary light reflexes are preserved.

Mechanical ventilation is usually employed when the equipment is available. The following are reasonable initial settings:

- Volume-control ventilation
- Tidal volume: Maximum 6 mL/kg of ideal body weight (calculate ideal body weight to avoid hyperinflation in larger patients)
- PEEP: 5 cm H_2O
- FiO_2: 100%, titrating to target adequate SpO_2
- Respiratory rate 14/min. The respiratory rate is adjusted to target a $PaCO_2$ of 35–45 mm Hg/$ETCO_2$ of 30–40 mm Hg. $ETCO_2$ is not a reliable surrogate for $PaCO_2$ in a hypovolemic patient. Frequent arterial blood gas (ABG) assays are utilized to adjust ventilation. For patients with suspected or diagnosed TBI, the $PaCO_2$ target is closer to 35 mm Hg. When metabolic acidosis is present, a lower $ETCO_2$/$PaCO_2$ may be beneficial to partially increase pH.

■ **Table 4-4: Post-Intubation management.**

Airway	• Secure the endotracheal tube • Continuous $ETCO_2$ monitoring (if available) • Assessment of airway patency • Chest x-ray and auscultation of breath sounds to exclude endobronchial (mainstem) intubation and pneumothorax • Aspiration of secretions
Breathing	• The next assessment step (clinical, chest x-ray, +/- ultrasound) • Potential evolving pneumothorax following application of positive pressure ventilation • Application of sedation, with or without paralysis, to optimize ventilation • Evaluate blood gas
Circulation	• Continue resuscitation • Manage potential decompensation associated with intubation and positive pressure ventilation • Potential administration of vasopressor medication to offset vasodilation due to sedation
Disability	• Exam limited by continual sedation and paralytic • Optimize TBI management (see Special Population Considerations) • Reassess neurologic exam, including pupils • Reapply C-spine collar if indicated
Exposure	• Anticipate hypothermia (exacerbated by sedation) and provide warming
ADJUNCTS ——	**Insert gastric tube (oral or nasal)**

ADJUNCTS TO TREATMENT

AWAKE INTUBATION

This advanced technique involves inserting an endotracheal tube under topical or regional anesthesia while the patient is awake or lightly sedated (i.e., interactive, cooperative, and maintaining airway patency and spontaneous ventilation). This is often performed with flexible video laryngo-tracheoscopy. Significant airway experience and specific training are important for safe practice of this technique, which is beyond the scope of the ATLS Course.

REASSESSMENT

Constant vigilance and frequent reassessment are necessary to detect any changes to the airway, even following attainment of a definitive airway. Rapid detection of compromised oxygenation and ventilation may prevent deleterious sequelae. Reassessment includes physical examination of the airway and of the airway device (including depth at the teeth or gums for an endotracheal tube, or at the neck for a surgical/incisional airway), oximetry, capnography (when available), and monitoring of ventilatory pressure. Airway devices may occlude from blood and secretions; suctioning is performed as needed when fluid is in the lumen. If device dislodgement is suspected, removal and reinsertion may be performed unless appropriate position is rapidly confirmed. Patient movement (e.g., log roll) is associated with displacement of airway devices. Attending to the airway during and following patient movement is important. Defined in ■ **Box 4-1**, the *DOPE* mnemonic is useful to recall potential causes of hypoxia or other clinical deterioration following intubation.

■ **Box 4-1: The DOPE Mnemonic.**

The "DOPE" Mnemonic	
D	**D**isplacement: Endotracheal tube displacement (right mainstem) or dislodgement
O	**O**bstruction: Mucous plug, kink in tubing
P	**P**neumothorax: Simple or tension, due to positive-pressure ventilation
E	**E**quipment failure: Disconnect from ventilator and perform manual ventilation

TRANSFER CONSIDERATIONS

Managing an airway emergency in a vehicle or aircraft is significantly more difficult. If airway compromise during transport is possible, intubation is often performed prior to a transfer. As mentioned above, attention to the airway and reassessment with any patient movement is important.

SPECIAL POPULATION CONSIDERATIONS

TRAUMATIC BRAIN INJURY

One of the goals of early management of TBI is to prevent secondary injury (see *Chapter 7, Disability: Neurological Assessment and Management*). During airway management, this goal is accomplished by avoiding hypotension, hypoxia, and hypercapnia. Hypotension and hypoxia are significant risks during intubation. Laryngoscopy and intubation without adequate sedation may increase blood pressure and ICP. Apnea produces hypercapnia and raises ICP and is minimized as much as possible.

LARGER PATIENTS

Increased adipose tissue presents anatomical and physiological airway challenges. Increased tissue mass presents different challenges to each airway management technique (mask ventilation, laryngeal mask insertion, intubation, and surgical/incisional airway). Adjuncts (e.g., oropharyngeal airways) may be beneficial when inserted early. Head-up positioning is useful. Modifications to medication doses may be indicated. Physiologically, hypoxia occurs more rapidly in larger patients due to higher incidences of preinjury pulmonary disease, lower respiratory compliance, and reduced functional residual volume. Application of higher levels of PEEP is often useful.

OBSTETRIC PATIENTS

In pregnancy, the airway is affected by potential reflux disease and regurgitation. The gravid uterus reduces functional residual volume, among other changes. From a management perspective, the challenges are very similar to those in the patient with higher proportion of adipose tissue.

OLDER PATIENTS

Soft-tissue changes reduce tissue turgor and can cause the cheeks to collapse (especially if dentures are removed), presenting challenges to maintain an adequate mask seal during mask ventilation. Conversely, removal of dentures facilitates intubation. Older patients are prone to hypotension following administration of RSI drugs due to physiology and the compounding of preinjury medications. The doses of RSI drugs are often reduced.

PEDIATRIC PATIENTS

Several differences in the pediatric airway are relevant to management, including the following:

- All airway structures are smaller (smaller equipment is indicated).
- The head is relatively larger. Therefore, the neck will tend to flex in infants and younger children laying on a flat surface unless padding is placed under the torso.
- The tongue and epiglottis are relatively larger. The larynx is more anterior and angled more anteriorly. Therefore, laryngoscopy is more challenging. Lifting the epiglottis with the laryngoscope can be helpful.
- The trachea is shorter. Thus, there is a greater risk of endobronchial or mainstem intubation.
- The cricoid is elliptical in infants and younger children and grows to circular by adulthood. Increased resistance may be felt at the cricoid during intubation.
- Increased metabolic rate and reduced functional residual capacity result in a higher risk of rapid hypoxemia, resulting in bradycardia and cardiac arrest much more quickly than in adults.

The endotracheal tube size can be estimated as: size = age/4 + 3.5. A cuffed endotracheal tube is safe and preferred for all age groups for emergency intubation. Laryngeal masks frequently have suggested patient weight ranges printed on the packaging or device. This may be useful for selecting an appropriately sized device. Drug doses are reduced and are based on weight. A height-weight tape and a pediatric resuscitation trolley with a drawer corresponding to each color bar on the tape are useful.

CHAPTER SUMMARY

Airway management encompasses a range of potential interventions, from basic maneuvers through upper airway devices and subglottic airway insertion. Intubation is not indicated for all injured patients. An airway may be opened and managed by basic airway maneuvers. Intubation may be safely temporarily deferred by these methods until resuscitation is initiated, competing priorities are addressed, and more resources are available. Intubation (excluding during cardiac arrest) is performed with a modified RSI process. Cardiovascular resuscitation is performed before and during RSI. Preoxygenation and apneic oxygenation are important to prevent hypoxia. Appropriate equipment including wide-bore suction is vital. The first attempt at endotracheal intubation is the optimal attempt and always have a plan for airway failure.

Direct airway injury is a rare and complicated presentation. Often the patient spontaneously assumes a position of breathing comfort, which may be temporarily maintained if oxygenation is adequate. A multidisciplinary team approach is beneficial to avoid exacerbating injuries with instrumentation. However, urgent intubation or a surgical/incisional airway may be needed to preserve life. Education, training, and practice will provide the clinician with the skills to proceed safely and effectively. For patients suffering high-percentage body surface area burn injury or presenting with a mechanism for potential inhalation injury, early intubation to preempt obstruction versus continuous observation with frequent reassessment remains a challenging decision.

KEY LEARNING POINTS

- **The most important priority in airway management is oxygenation.**
- **All emergent airway management is considered potentially difficult; every airway management must include a plan for failure.**
- **An airway may be managed without intubation, and intubation may be temporarily deferred until expertise is present.**
- **An airway device in the trachea with an inflated cuff below the vocal cords is termed a definitive airway.**
- **Initiate volume resuscitation before administration of RSI medications.**
- **Except in cardiac arrest, modified RSI is performed utilizing sedative and paralytic medications.**
- **The first attempt at intubation is the optimal attempt. Repeated attempts modify the technique or operator; identical repeated attempts are not likely to succeed.**
- **Successful intubation is confirmed with detection of sustained (present on at least seven breaths) exhaled carbon dioxide.**
- **For potential esophageal intubation, the tube is promptly removed and the airway maintained by reintubation and/or other methods.**
- **Surgical/incisional airway is indicated when oxygenation cannot be maintained by other means. Once the procedure is initiated, the clinician must persist and secure the airway regardless of any challenges encountered.**
- **Excellent teamwork, cognitive aids (e.g., checklists), and equipment selection will improve clinician performance and patient safety.**

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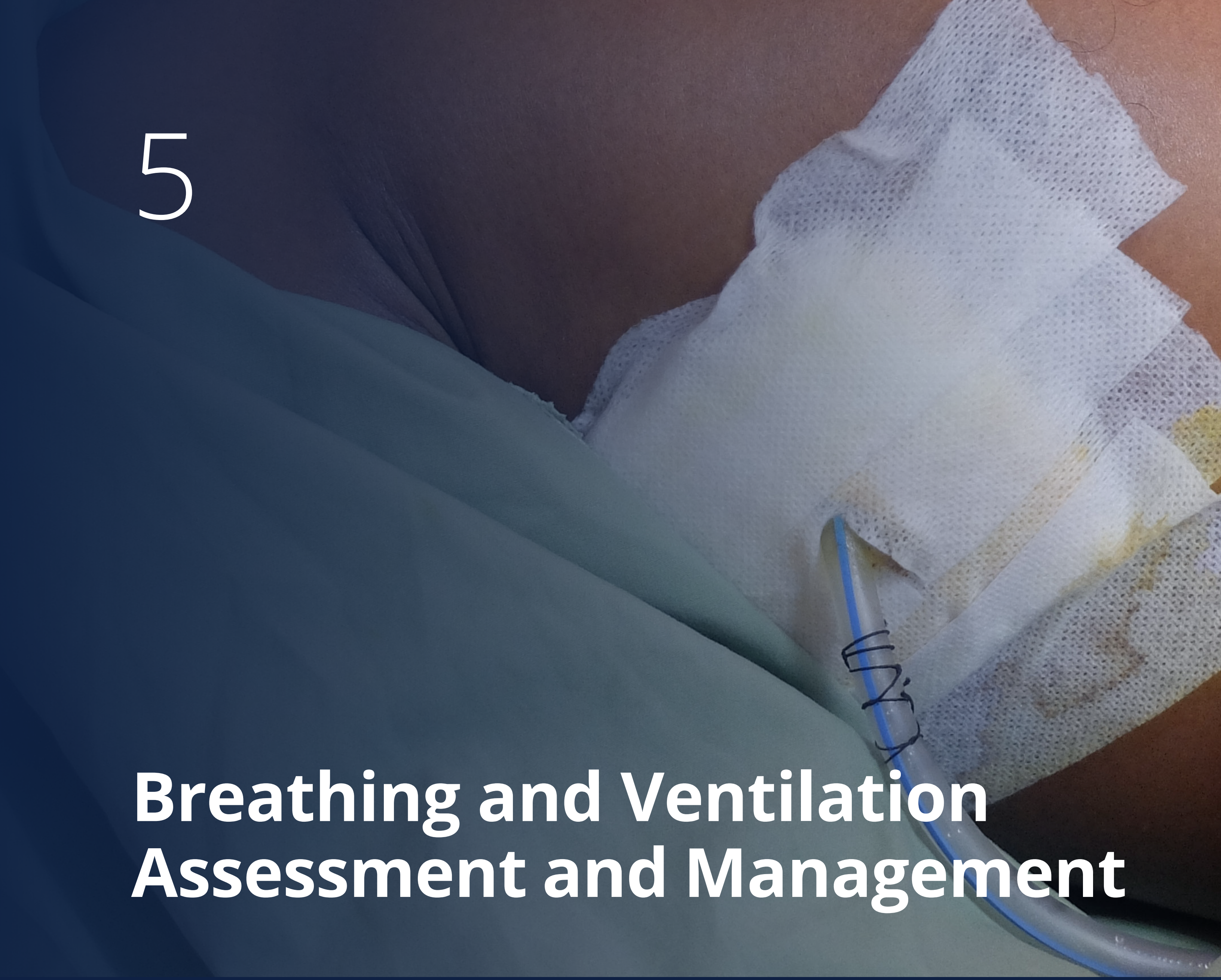


5

Breathing and Ventilation Assessment and Management

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will be able to do the following:

1. Define the anatomic landmarks of the chest/thorax
2. Explain the causes and presenting signs/symptoms of common conditions that result in respiratory distress following injury
3. Describe methods to diagnose various conditions that cause respiratory distress following injury
4. Discuss initial interventions to temporize or stabilize patients with respiratory distress following injury
5. Discuss diagnosis and management of traumatic conditions causing respiratory distress in pregnant, morbidly obese, and pediatric patients

5

Breathing and Ventilation Assessment and Management

CHAPTER STATEMENT

Thoracic trauma is very common and consists of both chest wall and intrathoracic organ injury. Blunt, penetrating, crush, or blast mechanisms are potential etiologies. Trauma to the chest may critically impair breathing, disrupting the processes of gas exchange and oxygenation. Delay in recognition or appropriate treatment can result in morbidity or death.

INTRODUCTION

Injury to the chest wall and the structures located in the thoracic cavity is one of the most common sequelae of trauma. Injuries can involve the boney structure of the chest wall, the viscera contained within the chest (heart, lungs, diaphragm, and esophagus), and the great vessels of the mediastinum. **Thoracic injury can produce impaired ventilation with respiratory acidosis, impaired oxygen exchange leading to metabolic acidosis, impaired cardiac function from structural or electrical injury to the heart, or massive hemorrhage.** There can also be more subtle injury whose consequences may not manifest for days to years, such as esophageal and diaphragmatic injury.

The clinician must understand the anatomy of the chest, the basic physiology of the cardiorespiratory system, and how to assess for various types of injury following trauma. As well, the clinician must be comfortable performing urgent procedures, such as tube thoracostomy, that can be used to temporize, and perhaps definitively treat, some injuries. As severe rib fractures account for significant mortality and morbidity, the clinician should be aware of multimodal strategies to offer pain relief and the clinical significance of severe chest wall injury.

This chapter will review the anatomic boundaries that define the chest. It will then review the pathophysiology underlying common injuries that result from trauma to the chest, how to assess for them, and how to start treatment. Alternative diagnostic strategies that may be employed in resource-limited settings are reviewed. The chapter ends by addressing how to alter needed interventions to address the special needs of pregnant patients, those who are morbidly obese, and pediatric patients.

ANATOMY

Based on surface landmarks, the chest is defined as the area from the sternal notch to the costal margin anteriorly and from the base of the neck to the costal margin posteriorly. However, the diaphragm can move extensively based on the depth of inspiration/expiration. Therefore, the abdomen can extend as high as the nipple line/inframammary fold (IMF) and tip of the scapula with deep exhalation. **■ Figure 5-1** illustrates the relationships between external landmarks and internal anatomy. **■ Figure 5-2** illustrates diaphragm movement.

While varying in position with age and gender, the nipple line intersects with the midclavicular line at the level of the fourth intercostal space. The IMF is usually along the fifth to sixth rib and is a more reliable landmark in patients with breast tissue than the nipple line. **The IMF is an important landmark, as it denotes the fourth to fifth intercostal spaces, where the pleural space can be safely decompressed with a needle or tube thoracostomy with less risk of entering the peritoneal cavity.**

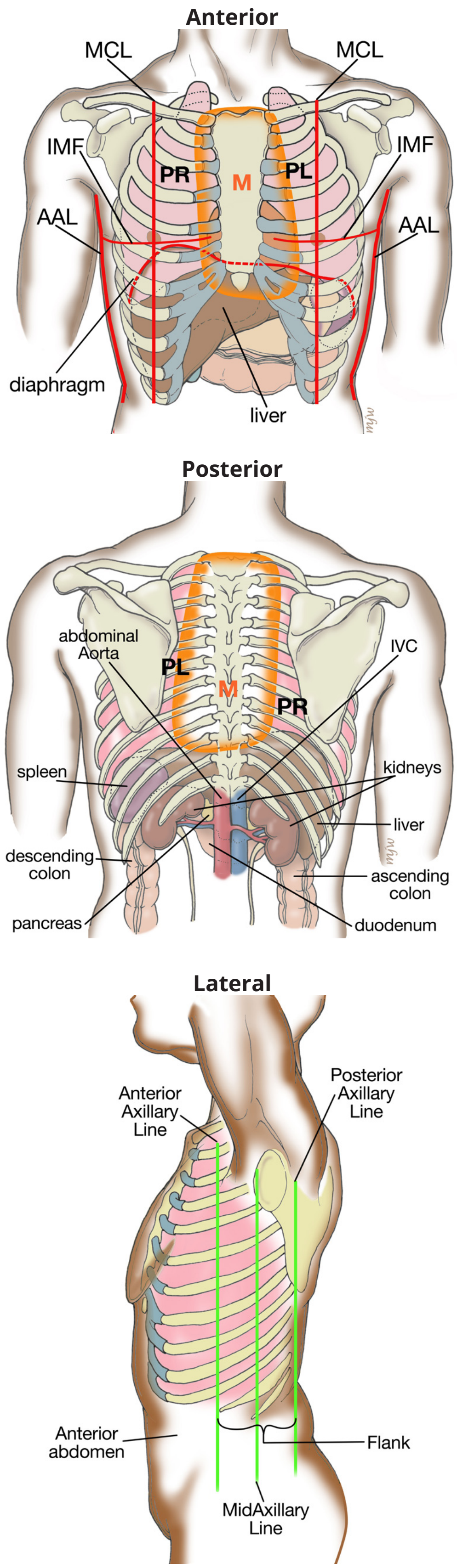
The bony structure of the thorax is composed of seven true ribs (ribs with direct cartilaginous connection to the sternum), three false ribs attached to the cartilage of rib 7, and two floating ribs (ribs 11 and 12). The sternum is comprised of the manubrium, body, and xiphoid and is connected to the ribs via the costosternal cartilage and costal margin.

The diaphragm separates the abdomen from the chest. The muscular diaphragm arises from the sternum and ribs anteriorly and laterally, and from the L1–L3 vertebral bodies posteriorly. The central component of the diaphragmatic dome is a tendinous aponeurosis. Near the midline, this tendon is attached to the pericardium, an anatomic relationship that can result in diaphragmatic injuries extending into the pericardial sac.

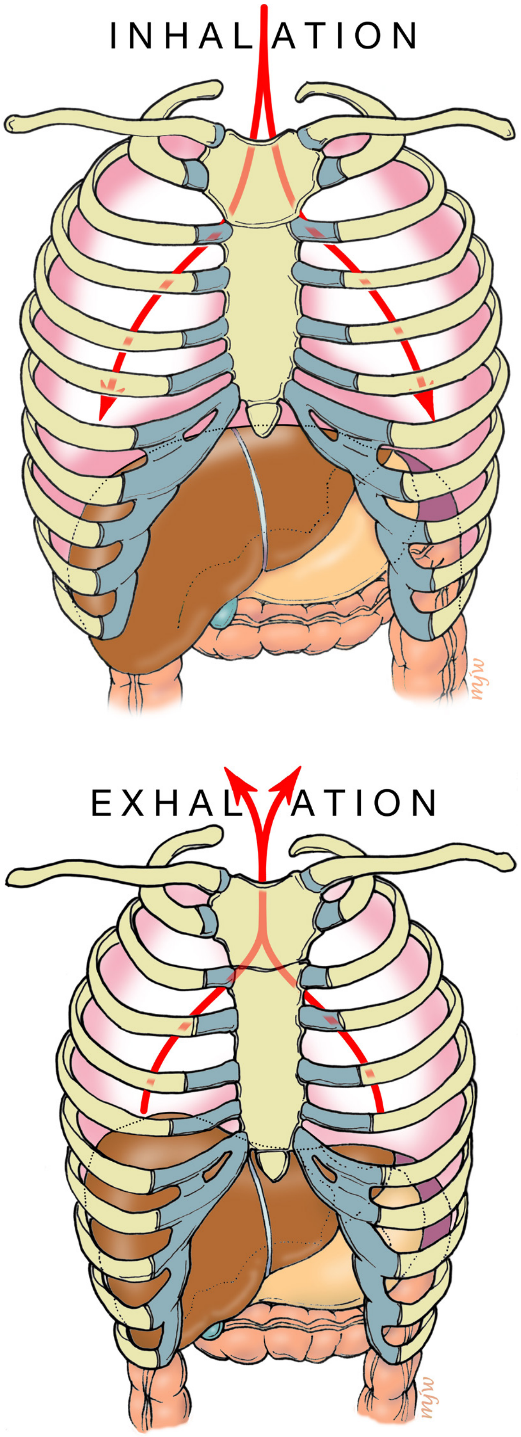
Several muscles contribute to the structure and function of the chest wall. Inferiorly, the diaphragm forms the inferior boundary of the chest. Anteriorly, the pectoralis major and minor, serratus anterior, intercostal, and superior bounds of the external oblique muscles are present. Posteriorly, the chest is protected by the latissimus dorsi, the ascending, transverse, and descending portions of the trapezius, the rhomboid major and minor, the serratus posterior, and the erector spinae.

The chest is divided into two pleural cavities (right and left) and a mediastinal cavity. The pleural space is the space between the chest wall and each lung. Externally, the mediastinum may be visualized as a "box" defined as the area medial to the nipple lines anteriorly, medial to the tips of the scapulae posteriorly, and bounded superiorly by the sternal notch and inferiorly by the costal margins. **■ Figure 5-3** illustrates the cardiac "box." **Penetrating injuries to the cardiac "box" alert the clinician to potential damage to the great vessels, pulmonary hilar structures, and heart.**

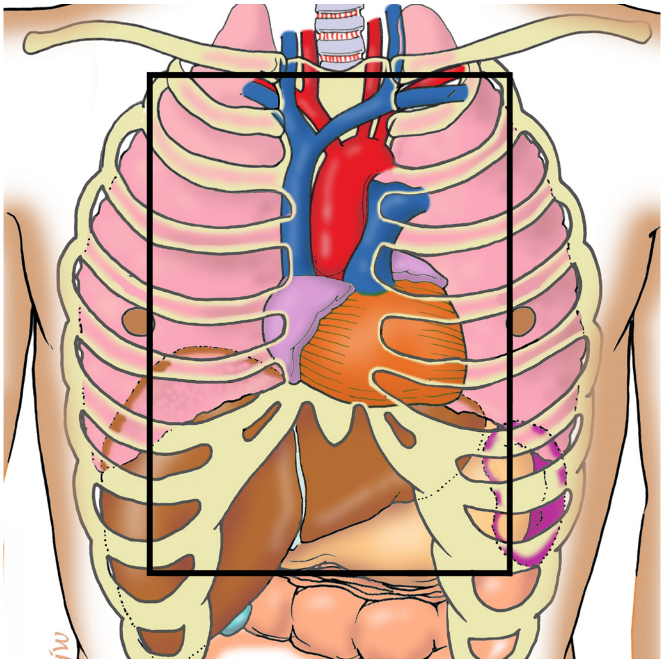
■ **Figure 5-1: Internal anatomy of the Thoracic and Upper Abdomen as Related to External Landmarks.** **IMF** – inframammary fold; **AAL** – anterior axillary line; **PAL** – posterior axillary line; **PR** – right pleural cavity; **PL** – left pleural cavity; **M** - mediastinal cavity.


Anterior
MCL
MCL
IMF
IMF
PR
M
PL
AAL
AAL
diaphragm
liver
Posterior
abdominal Aorta
PL
M
PR
IVC
spleen
kidneys
liver
descending colon
ascending colon
pancreas
duodenum
Lateral
Anterior Axillary Line
Posterior Axillary Line
Anterior abdomen
Flank
MidAxillary Line

■ **Figure 5-2: Alteration of Anatomy with Respiration.** As the diaphragm moves, intra-abdominal structures occupy more (exhalation) or less (inhalation) of the rib cage.


INHALATION
EXHALATION

■ **Figure 5-3: The Cardiac "Box".** The cardiac "box" is defined by the area medial to the nipple lines anteriorly, medial to the tips of the scapulae posteriorly, bounded superiorly by the sternal notch and inferiorly by the costal margins. Penetrating injuries to this region have potential to injure several vital structures.



The *flank* is the area between the anterior and posterior axillary lines. A penetrating injury to the left flank from the nipple level to the costal margin may be related to a diaphragm injury. A neurovascular bundle runs along the inferior border of each rib, with the intercostal vein superior to the intercostal artery and the artery superior to the intercostal nerve. **Needles and chest tubes are placed immediately over the superior aspect of a rib to minimize potential injury to the neurovascular structures.**

PATHOPHYSIOLOGY OF COMMON INJURIES

The function of the chest wall is twofold. It enables volumetric change of the thoracic cavity, which facilitates lung expansion and contraction, and it protects underlying visceral structures. The primary muscles of respiration are the diaphragm and the intercostal muscles. During inspiration, the diaphragm contracts inferiorly into the abdomen. Concurrently, the intercostal muscles contract, producing superior and anterior movement of the sternum and causing the ribs to move laterally and superiorly. Chest wall structures move in an opposite fashion during exhalation. The resultant volume changes cause a pressure differential between the lung and the atmosphere, which drives gas into and out of the lung. Normal respiratory rate at rest in the uninjured patient is 8–12 breaths per minute. **Whereas CO_2 exchange is mostly dependent on adequate tidal volume (minute ventilation) and blood flow to the alveoli, oxygen exchange is dependent on functioning alveolar units and FiO_2. Impaired ventilation and CO_2 exchange can manifest as altered mental status and hypotension (a late finding). Hypoxemia can manifest as impaired mental status and cyanosis.**

When chest injuries occur, normal physiologic mechanisms can be disrupted. Pulmonary contusion/alveolar hemorrhage or changes in intrathoracic pressure relationships, as may occur with a hemo-/pneumothorax, can impair gas exchange with resultant hypoxemia and hypercapnia. Tension hemo-/pneumothorax results in increased intrathoracic pressure, which can impede venous return to the heart with resultant hypotension. Multiple rib fractures result in pain or paradoxical chest wall movement, which can impair lung expansion. The common results of severe thoracic trauma are hypoxemia, hypercapnia, and hypotension with acidosis.

PULMONARY CONTUSION PATHOPHYSIOLOGY

Pulmonary contusion is an injury to the alveolar capillaries without a tear in the lung tissue. **This is the most common intrathoracic injury,** although there may not be clinical consequences. Pulmonary contusions can occur in the presence or absence of rib fractures. **Secondary to flexible cartilaginous chest walls, lack of fracture is more common in the pediatric population.** The majority of younger patients with isolated pulmonary contusions recover. However, the mortality rate associated with development of long-term respiratory failure in the multiply injured patient is substantial. Blunt mechanism of injury produces a contusion by transmission of force to the lung. Penetrating and explosive mechanisms cause contusion either by direct lung injury or by cavitation effect.

Pulmonary contusion results in alveolar damage with blood and fluid accumulation in the pulmonary tissues. A mismatch between ventilation and perfusion occurs, thereby creating an intrapulmonary shunt and segmental lung damage with loss of lung compliance. These pathophysiological effects can lead to hypoxemia and hypercapnia. **The size, severity, and clinical impact of contusion frequently increase during the first 24–72 hours following injury.**

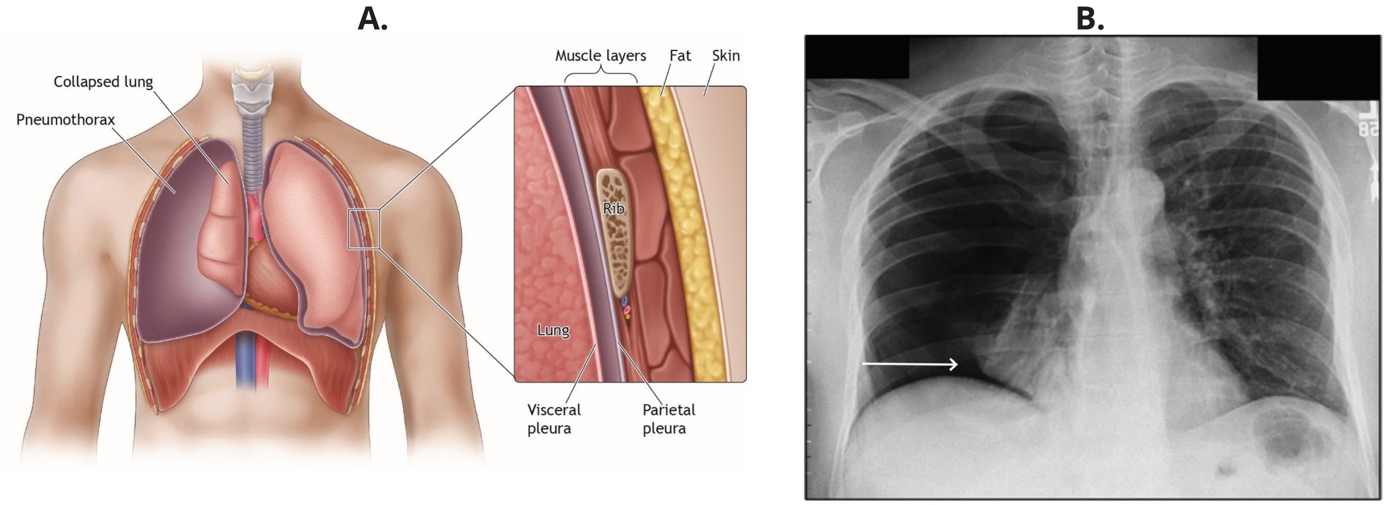
PNEUMOTHORAX PATHOPHYSIOLOGY

A pneumothorax results from air entering the space between the lung and the pleura. This can be due to a defect in the lung or a defect in the chest wall that communicates with the pleural space. Each pleural cavity is filled by the lung. Air in the pleural space disrupts the normal apposition of the lung to the chest wall, causing the lung to collapse. This is defined as a *simple pneumothorax.* ■ **Figure 5-4** illustrates a simple pneumothorax.

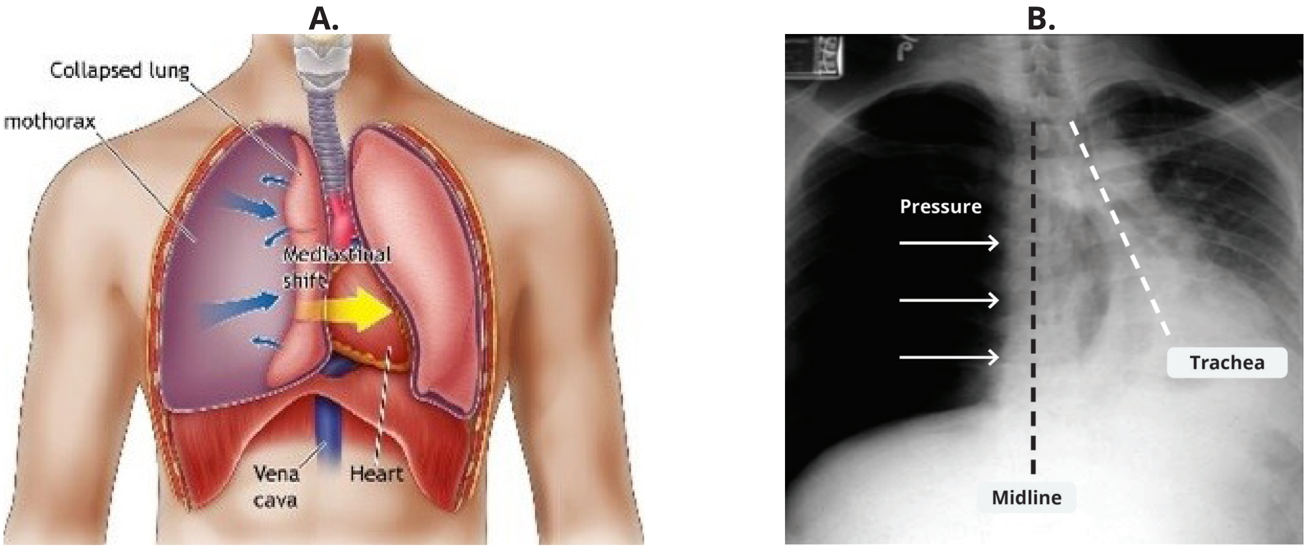
Traumatic etiologies include parenchyma injury from high airway pressure, stabbing injury, firearm injury, puncture from rib fracture, or iatrogenic events as may occur during central venous catheter insertion. Progressive accumulation of air and or fluid in the pleural space further collapses the affected lung and pushes the mediastinum to the opposite side, converting a simple pneumothorax to a *tension pneumothorax.* ■ **Figure 5-5** illustrates tension pneumothorax physiology.

Such **mediastinal shift impedes venous return to the heart, thereby decreasing cardiac output and, eventually, systemic blood pressure. A simple pneumothorax can quickly become a tension pneumothorax if the patient is receiving positive-pressure (e.g., mechanical, bag) ventilation.** Up to 19% of patients who die following a blunt mechanism of injury have a pneumothorax. Depending on other injuries present, emergent decompression of the pleural space may be lifesaving.

■ **Figure 5-4: Simple Pneumothorax. A.** Pneumothorax results from air entering the potential space between the visceral and parietal pleura. **B.** Chest x-ray (CXR) demonstrating near complete right pneumothorax. Arrow marks edge of right lung.



■ **Figure 5-5: Tension Pneumothorax.** A "one-way valve" air leak occurs from the lung or through the chest wall. Air is forced into the thoracic cavity, eventually collapsing the affected lung. **A.** Diagram demonstrating shift of mediastinum and increased pressure on the caval vessels in right tension pneumothorax. **B.** Chest radiograph immediately on patient presentation demonstrating right tension pneumothorax. The trachea is deviated to the left of the midline.

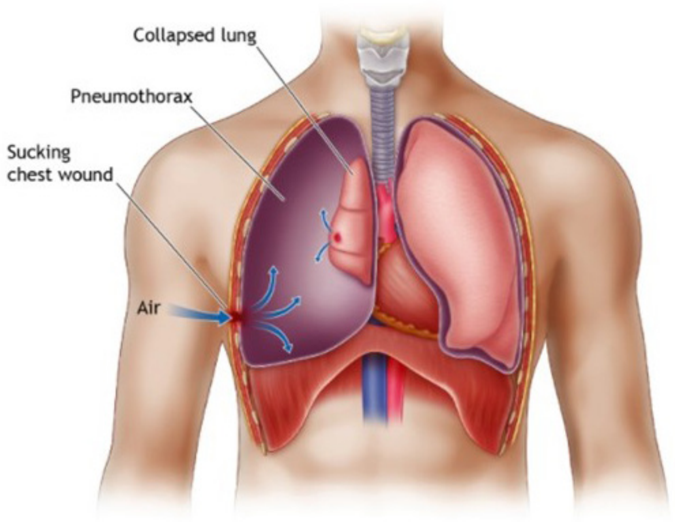


Lacerations to the chest wall with penetration of the pleural space can result in an **open pneumothorax, or a "sucking chest wound."** Because air follows the path of least resistance, when an opening in the chest wall is at least two-thirds the diameter of the trachea, air will preferentially pass through the chest wall defect on inspiration, creating a distinct "sucking" sound. Equilibration between intrathoracic and atmospheric pressure is immediate. Effective lung expansion is impaired, leading to hypoxemia and hypercapnia. ■ **Figure 5-6** illustrates an open pneumothorax.

HEMOTHORAX PATHOPHYSIOLOGY

Hemothorax occurs when blood accumulates between the lung and chest wall. This can be due to hemorrhage from direct injury to the lung, a severed intercostal vessel, broken ribs, injured thoracic viscera, **or an abdominal injury entering the chest via a defect in the diaphragm.** A penetrating injury to the heart can result in hemothorax if there are concurrent pericardial and pleural defects. Massive or tension hemothorax occurs when sufficient blood collects in the pleural space to cause hypotension, which is due to the combined effects of impaired venous return (like with tension pneumothorax) and hemorrhagic loss of circulatory volume.

■ **Figure 5-6: Open Pneumothorax.** Large defects of the chest wall that remain in communication with the atmosphere can result in an open pneumothorax.



RIB FRACTURE AND FLAIL CHEST PATHOPHYSIOLOGY

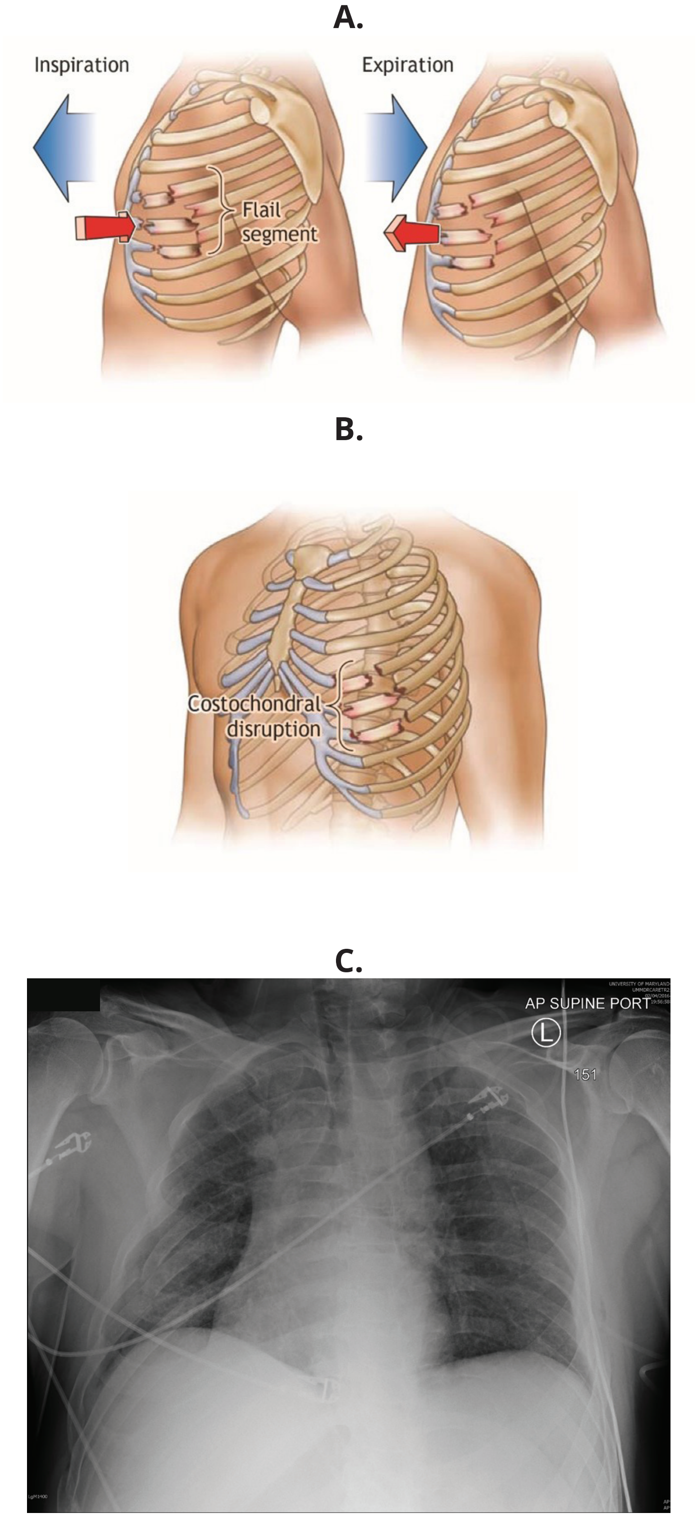
Rib fractures occur along a spectrum, from simple nondisplaced fractures to displaced, complex rib fractures. Fractures can be segmental and, when occurring in multiple places along adjacent ribs, may result in a radiographic flail segment or clinical flail chest. **A radiographic flail segment is defined as two or more ribs broken in two or more places as visualized on an imaging study. Clinical flail chest is defined as paradoxical movement of the chest wall during respiration.** It is possible to have radiographic flail without clinical flail chest, but the opposite does not occur.

Paradoxical movement occurs because the flail segments are no longer attached to the chest wall, causing the injured portion of the chest wall to move inward with spontaneous inspiration (due to negative intrathoracic pressure) and outward with exhalation. ■ **Figure 5-7** illustrates flail chest. During positive-pressure (mechanical) ventilation, paradoxical movement is reduced and can be difficult to detect. Rib fractures may result in progressive hypercapnic respiratory failure due to pain-limited inspiration. **Severe hypoxemia (when present) is due to concomitant pulmonary contusion and/or pneumothorax.**

DIAPHRAGM INJURY PATHOPHYSIOLOGY

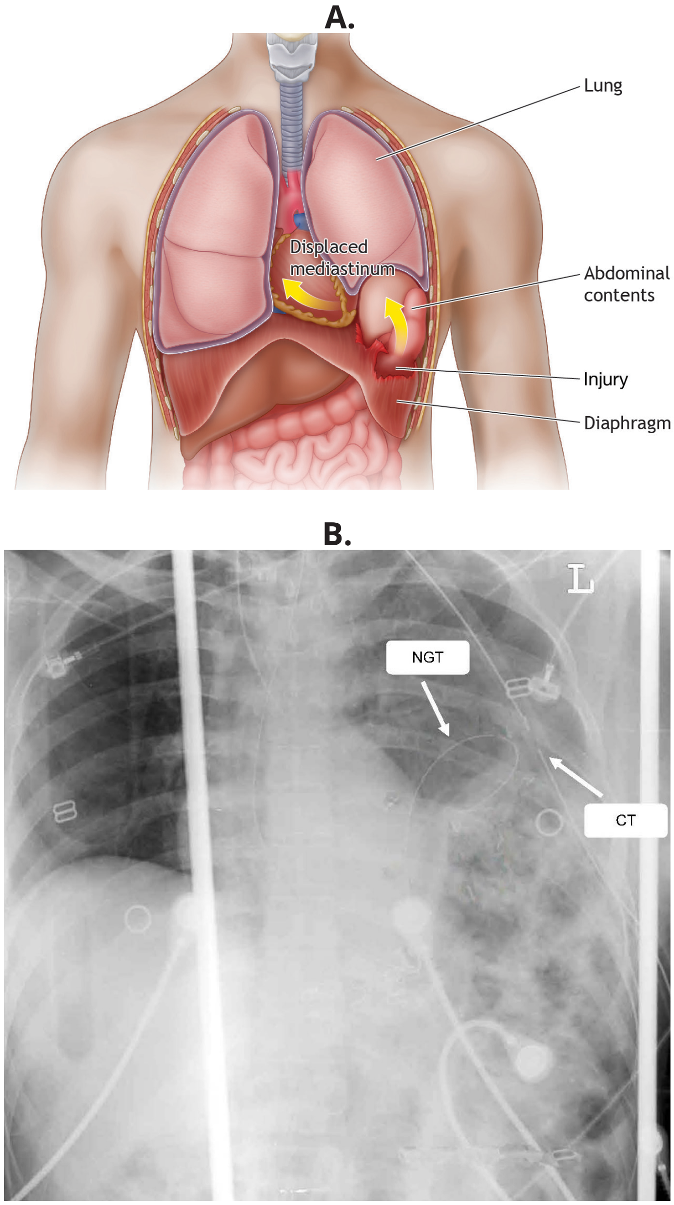
Traumatic diaphragm injuries are present in approximately 0.5% of all trauma patients, with two-thirds of cases due to penetrating mechanisms. Traumatic diaphragm ruptures following blunt trauma are more commonly diagnosed on the left side, likely because the liver protects the right diaphragm. Blunt trauma produces large radial tears, whereas penetrating injury more commonly produces smaller localized perforations which may be more difficult to diagnose (80% are <2 cm).

■ **Figure 5-7: Flail Chest.** **A.** The flail chest segment from multiple rib fractures disrupts normal chest wall movement. **B.** Flail chest from costochondral separation. **C.** CXR with multiple rib fractures and pulmonary contusion. A segment of the chest wall does not have bony continuity with the rest of the thoracic cage.



Both mechanisms can result in acute or chronic (i.e., years until diagnosed) herniation of abdominal viscera. **Diaphragmatic rupture can result in respiratory compromise through mechanical lung compression by herniated visceral contents.** ■ **Figure 5-8** illustrates diaphragm injury.

■ **Figure 5-8: Diaphragm Injury. A.** Blunt injury produces radial tears which allow herniation of abdominal contents into the thoracic cavity. Respiratory distress is frequently present. Tension physiology may occur as abdominal viscera displace the mediastinum. **B.** CXR demonstrating nasogastric tube (NGT) above the diaphragm in a blunt trauma patient, diagnostic of gastric herniation through a diaphragm injury. A Chest tube (CT) is also present.



TRACHEOBRONCHIAL INJURY PATHOPHYSIOLOGY

Injury to the trachea or a major bronchus is an unusual but potentially fatal condition. Most tracheobronchial injuries occur within 1 inch of the carina. Patients who reach the hospital alive with these injuries have a high mortality rate from associated injuries, inability to ventilate due to loss of tidal volume, inadequate airway, or development of a tension pneumothorax. Such severe injury can result from crushing forces, shear forces due to rapid deceleration, or penetrating trauma.

ASSESSMENT FOR COMMON INJURIES

Efficient examination of the chest follows a "look, listen, feel" (inspection, auscultation, palpation) approach. The chest and neck are completely exposed to allow for assessment of neck veins, tracheal position, and surface signs of injury, such as bruising or laceration. Temporary removal of the front of the cervical collar, when present, is necessary to visualize the neck. Manual spinal motion restriction is maintained during this portion of the exam (*see Chapter 4, Airway Assessment and Management* **Figure 4-12** for illustration of technique).

The chest wall is visualized for symmetrical movement. Respiratory distress may be indicated by intercostal and supraclavicular muscle retractions, nasal flaring, or the patient speaking in short sentences. Auscultation anteriorly, in the second to third rib spaces, and laterally, in the fifth to sixth rib spaces, is performed for the presence and quality of breath sounds. Diminished sounds may indicate hemo-/pneumothorax, large pulmonary contusion, or diaphragm injury with herniated abdominal contents. If endotracheal intubation has been performed, diminished breath sounds may indicate bronchial mainstem intubation, a particular risk in children due to a shorter trachea. Palpation may detect tenderness (suggestive of rib fractures) or crepitus (suggestive of a pneumothorax). The chest wall includes the lateral and posterior thorax. Therefore, these areas are also assessed either anteriorly or following a log roll procedure.

Significant yet often subtle signs of chest injury include increased respiratory rate and changes in the breathing pattern, often manifested by progressively shallower respirations. Cyanosis may be a late sign of hypoxemia. **Cyanosis may be recognized earlier by examining the nail beds and lips. Both hypoxemia and hypercapnia can present as altered mental status. Injured patients who are agitated, confused, or obtunded are assumed to have impaired pulmonary gas exchange until proven otherwise.** ■ **Table 5-1** lists physical signs of several conditions.

PULMONARY CONTUSION ASSESSMENT

Clinical presentation is dependent on degree of injury, comorbid disease, and concomitant injuries. Pulmonary contusion may be asymptomatic. When severe, dyspnea, tachypnea, or hypoxemia may be present, auscultation may detect rales and decreased respiratory sounds. Wheezing, cough, bronchorrhea, and blood-streaked sputum are signs of more advanced injury. Respiratory distress severity, hypoxia, and hypercapnia typically peak at around 72 hours postinjury. Clinical deterioration may occur in a delayed fashion.

■ Table 5-1: Physical Signs of Breathing Disorders and Injuries.

	PHYSICAL SIGN				
Condition	**Breath Sounds**	**Tracheal Position**	**Neck Veins**	**Blood Pressure**	**Comment**
Pulmonary Contusion	Normal to Decreased	Midline	Unaffected	Unaffected	Signs vary based on severity
Simple Hemo/ Pneumothorax	Normal to Decreased	Midline	Unaffected	Unaffected	
Tension Hemo/ Pneumothorax	Decreased	Deviated AWAY from injury	Distended*	Decreased	Critical clinical diagnosis
Open Pneumothorax	Abnormal and decreased	Midline	Unaffected	Unaffected	Chest wound
Massive Hemothorax	Decreased	Midline**	Flat	Decreased	Hemorrhagic shock
Flail Chest	Decreased	Midline	Unaffected	Unaffected	Severity of associated pulmonary contusion determines degree of hypoxia
Diaphragm Injury	Decreased	Midline**	Unaffected***	Unaffected***	
Tracheobronchial	Decreased and abnormal	Midline**	Unaffected****	Unaffected	Continued air leak after chest tube insertion. Potential for massive subcutaneous empysema.

* Distended neck veins are difficult to assess and may be absent if concurrent hemorrhagic shock is present.
** May shift away from injury side if tension physiology.
*** Massive herniation of abdominal contents into left chest may produce tension physiology. Neck veins may be distended and blood pressure decreased if tension physiology. Blood pressure may be decreased if hemorrhagic shock is present due to abdominal injury.
**** May be distended if concurrent tension pneumothorax.

SIMPLE, TENSION, AND OPEN PNEUMOTHORAX ASSESSMENT

Pneumothorax presents with dyspnea and possibly diminished breath sounds over the affected pleural cavity. Crepitus may be detected on palpation. **Tension pneumothorax causes absent breath sounds on the affected side, hypotension, and tracheal deviation away from the side of injury**, as illustrated in **■ Figure 5-5**. However, tracheal deviation is difficult to assess on physical exam and may be a subtle dislocation in the suprasternal notch or identified only on a chest radiograph. **Tension pneumothorax is a clinical diagnosis based upon mechanism, absent breath sounds, and hypotension. Emergent treatment is not delayed to confirm the diagnosis by radiographic or ultrasound studies.**

Assessment for open pneumothorax involves identifying the chest wall defect. Often, the distinct sucking sound associated with inspiration will help identify the injury. Clinical signs and symptoms are appropriate mechanism of injury, pain, difficulty breathing, tachypnea, decreased breath sounds on the affected side, and noisy movement of air through the chest wall injury. Breath sounds may be diminished depending on the size of the open pneumothorax.

HEMOTHORAX ASSESSMENT

Hemothorax will present like pneumothorax, with dyspnea and possible diminished breath sounds. A small hemothorax may not be evident on physical exam, whereas a large hemothorax can present with decreased breath sound on the affected side. Massive hemothorax will present with decreased breath sounds and hemorrhagic shock (*see Chapter 6, Circulation Assessment and Volume Resuscitation*). Tension hemothorax will present with decreased breath sounds associated with hypotension (like tension pneumothorax). The decreased blood pressure is due to both impaired venous return to the heart (as in tension pneumothorax) and decreased circulatory volume due to hemorrhage.

RIB FRACTURES AND FLAIL CHEST ASSESSMENT

In conscious patients, severe chest wall injury manifests as pain with inspiration or exhalation, commonly evidenced by an inability to take a deep breath or to speak in complete sentences. Frequently, the patient will not want to move due to pain. Flail chest is a clinical diagnosis. As mentioned earlier, a radiographic flail segment may be present without clinical flail chest. Paradoxical chest wall movement may be difficult to observe and may not occur during positive-pressure ventilation. Crepitus may be palpated due to movement of the fracture segments or due to subcutaneous air. Palpation of the chest wall will elicit pain.

DIAPHRAGM INJURY ASSESSMENT

Diaphragm injury may not be detected on physical examination. When present, the signs and symptoms are related to the effects of herniation of abdominal visceral structures into the chest. A large left diaphragm tear may produce dyspnea, hypoxemia, and hypercapnia due to inability of the lung to fully expand. **A hemothorax may be the result of combined diaphragmatic and intra-abdominal injury.** Negative intrathoracic pressure causes blood to accumulate in the chest through the defect in the diaphragm. Rarely, and very difficult to detect, bowel sounds may be heard over the left chest if intestine has herniated.

TRACHEOBRONCHIAL INJURY ASSESSMENT

Hemoptysis, cervical subcutaneous air, tension pneumothorax, and cyanosis are typical signs of an injury to the larger airways. For patients receiving mechanical ventilatory support, a loss of inhaled tidal volume into the chest wall or through a tube thoracostomy may markedly impair ventilation. **Incomplete expansion of the lung and a continued large air leak after placement of a chest tube suggest a tracheobronchial injury.**

ADJUNCTS TO ASSESSMENT

MONITORING OXYGENATION AND VENTILATION

Continuous pulse oximetry monitoring of arterial SpO_2 is beneficial. However, a low SpO_2 reading may occur due to poor perfusion at the oximeter location, as well as due to a primary pulmonary process. If available, $ETCO_2$ detected using colorimetry, capnometry, or capnography can provide valuable insight into ventilation. However, $ETCO_2$ values are also influenced by pulmonary perfusion (*see Chapter 4, Airway Assessment and Management*). An arterial blood gas (ABG) assay is a more precise method to accurately diagnosis and quantify hypoxemia and hypercapnia. Additionally, ABG provides information regarding acid-base balance.

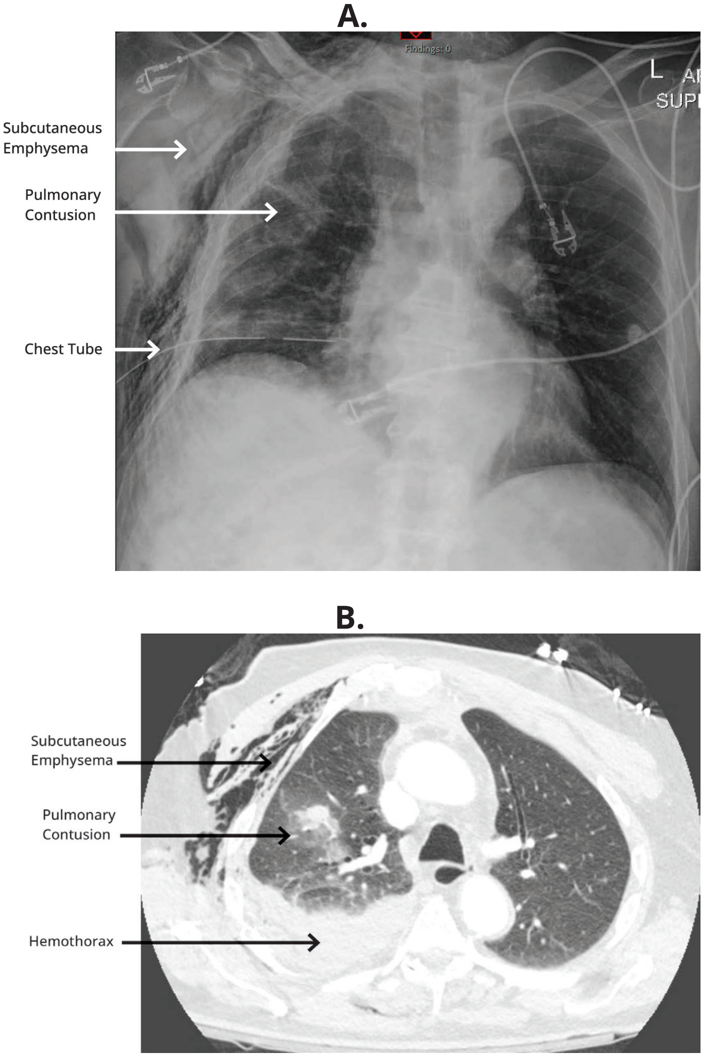
IMAGING

CHEST RADIOGRAPHY

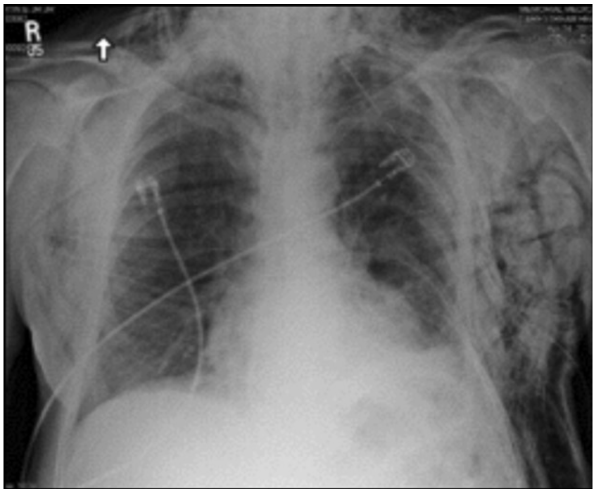
Anterior-posterior (AP) chest x-ray (CXR) is one of the most common and readily available imaging adjuncts available. Images can be obtained in the resuscitation area with a portable unit. The CXR is reviewed for lung expansion, presence of fluid, widening of the mediastinum, subcutaneous and mediastinal air, midline tracheal shift, loss of aortic anatomic detail, and presence of gastric air in the left chest

Multiple rib fractures and fractures of the wide, thick, and protected first or second rib suggest that a significant force was delivered to the chest and underlying organs. Blood layers in dependent positions, and air rises anteriorly. Therefore, on a supine CXR, a hemothorax may appear as mild lung opacity. A pneumothorax may manifest as hyperlucency or may not be visible. Pneumomediastinum is a sign of injury to the airway or digestive tract (e.g., esophagus; *see Chapter 21, Thoracic, Abdominopelvic, and Genitourinary Trauma*). **■ Figure 5-9** and **■ Figure 5-10** illustrate various chest injuries on radiologic imaging.

■ Figure 5-9: CXR and CT Scan Images of Pulmonary Injuries. A. CXR demonstrates subcutaneous emphysema, pulmonary contusion, and chest tube. **B.** CT scan demonstrates the same findings along with a hemothorax.



■ **Figure 5-10: Massive Subcutaneous Pneumothoraces.** Subcutaneous air infiltrates the subcutaneous and muscular tissues, outlining the chest musculature.



ULTRASOUND

FAST and eFAST are useful for rapid detection of pneumothorax, hemothorax, and hemopericardium. Accurate diagnosis depends on a clinician's skill and experience. These studies can be performed in the resuscitation area and can be repeated, as they do not involve radiation.

CT SCAN

CT scan is a more sensitive imaging modality and provides much more detailed anatomic information than either plain x-ray or ultrasound. However, in many institutions, transport out of the resuscitation area is required. Radiation exposure, time consumption, and expense are negatives of this modality.

ADJUNCTS FOR THE DIAGNOSIS OF SPECIFIC INJURIES

PULMONARY CONTUSION

A pulmonary contusion appears as a pulmonary infiltrate on CXR that is not restricted by the anatomical lobes or segments. There may or may not be associated rib fractures. An average of 6 hours passes before the characteristic infiltrate appears on a CXR, but sometimes the contusion may be evident immediately or not for 48 hours. Other conditions such as hemothorax or pneumothorax can interfere with the ability to visualize a pulmonary contusion on CXR. CT is very sensitive for pulmonary contusion detection as seen in ■ **Figure 5-9**. The volume of lung involvement on CT correlates with clinical outcomes. Unlike CXR, CT can detect contusion almost immediately after injury. CT findings of pulmonary contusion consist of nonsegmental areas of consolidation and ground-glass opacification (hazy gray areas that indicate increased density).

PNEUMOTHORAX AND HEMOTHORAX

Simple pneumothorax can be diagnosed using CXR, ultrasound, or CT scan. CT scan is the most sensitive modality and can detect conditions that are otherwise occult on x-ray or ultrasound. AP CXR can miss an anterior simple pneumothorax. Following trauma, the presence of subcutaneous air on CXR usually denotes the presence of a pneumothorax. ■ **Figure 5-9** and ■ **Figure 5-10** illustrate subcutaneous emphysema. A pneumothorax that is seen only on chest CT is frequently referred to as an "occult pneumothorax." Hemothorax can be seen using CXR, ultrasound, or CT scan.

RIB FRACTURE

Rib fractures are best detected using CT scan. In most centers, CT scan has replaced "rib series" radiographs, as CT provides more detailed information regarding location and degree of severity (i.e., displacement) of the fracture and allows for evaluation of concurrent lung injury. Chest CT can quantitate the number of fracture segments (diagnosing radiographic flail chest) and detect associated pulmonary contusion, hemothorax, and pneumothorax.

DIAPHRAGM INJURY

Diaphragm injuries are very difficult to diagnose on CXR unless abdominal viscera have herniated into the chest. The abnormality can be misinterpreted as an elevated hemidiaphragm, loculated pneumothorax, or subpulmonic hematoma. An elevated right diaphragm on a CXR may be the only sign of a right diaphragm injury. A recent review reported that the sensitivity of CT scan with enteral contrast for diagnosis of traumatic diaphragmatic hernia was only 80%. If a tear of the left diaphragm is suspected, a nasogastric tube (NGT) can be inserted. If the tube appears superior to the diaphragm on the CXR, a diaphragmic defect is suspected ■ **Figure 5-8B**, illustrates an NGT in this position. The diagnosis of diaphragm injury is confirmed by operative exploration. Minimally invasive techniques, such as laparoscopy, may be employed when diagnosis is unclear.

Isolated diaphragmatic injuries are rare. The force required to create a blunt diaphragm injury almost always causes additional thoracoabdominal injuries. These may vary from simple rib fractures to multiple herniations of lacerated viscera. Even isolated penetrating diaphragmatic lacerations typically have injuries to adjacent structures, such as the liver, lung, heart, ribs, spleen, stomach, colon, esophagus, vertebral column, or spinal cord. Careful assessment for other thoracic or abdominal injuries is always indicated. A diaphragm injury may be present following a stab wound below the level of the nipple on the left chest and flank region. Firearm-related injuries in this region are frequently treated with operative exploration. Thus, the evaluation for a diaphragmatic injury is performed intraoperatively.

TRACHEOBRONCHIAL INJURY

Bronchoscopy confirms the diagnosis of tracheobronchial injury. CT is useful to assess the airways and lungs and to evaluate potential hemothorax and pneumothorax.

INTERVENTIONS AND TREATMENTS

Supplemental oxygen is recommended at least during the primary survey, until patient acuity can be further assessed and the risk of respiratory compromise determined.

PULMONARY CONTUSION MANAGEMENT

The injured lung is prone to pulmonary edema due to extravascular fluid accumulation, and the volume of a contused lung may increase over the first 24–72 hours following injury. Oxygen exchange may be gradually impaired with progressive hypoxemia. Treatment includes administration of supplemental oxygen to maintain adequate saturation and avoiding volume overload while supporting circulatory function. Fluid balance can be challenging in cases of severe contusion. Mechanical ventilation or other advanced adjuncts may be instituted to maintain appropriate SpO_2. An injured lung has an impaired ability to clear secretions, and an estimated 20% of patients with pulmonary contusion develop pneumonia. Thus, pain control and pulmonary hygiene are central to the management of pulmonary contusion (see Rib Fractures and Flail Chest Management).

PNEUMOTHORAX MANAGEMENT

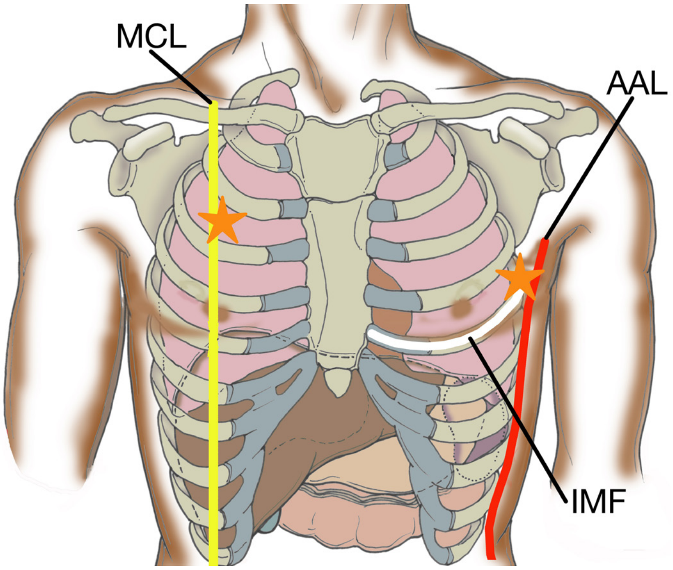
SYMPTOMATIC SIMPLE AND TENSION PNEUMOTHORAX MANAGEMENT

Treatment by tube thoracostomy is dependent on the size and clinical effect of the pneumothorax. **Clinical diagnosis of tension pneumothorax mandates emergent chest decompression, which can be achieved rapidly by either needle catheter or finger thoracostomy.** Needle catheter thoracostomy involves insertion of a large-bore (e.g., ≥ 14 gauge), over-the-needle catheter. There are two optimal locations for needle catheter insertion: the fifth intercostal space (approximately at the IMF) between the mid and anterior axillary lines; and at the second intercostal space at the midclavicular line. ■ **Figure 5-11** illustrates potential locations for needle thoracostomy. The choice of site is dependent on patient factors and clinical scenario. The benefit of needle thoracostomy is expediency. However, due to variable thickness of the chest wall, kinking of the catheter, and other technical or anatomic complications limit the success and duration of needle decompression.

Finger thoracostomy is another approach for emergent decompression of the chest. A scalpel is used to create an opening in the chest wall at the fifth intercostal space (approximately at the IMF) between the mid and anterior axillary lines as part of chest tube insertion. A finger is inserted into the pleural space to release air and fluid. **A tension pneumothorax can recur following either finger or needle decompression**, as the soft tissues of the chest can occlude the tract that was created. **Insertion of a tube thoracostomy is performed following emergent decompression.** Serial release of air may be indicated until a tube thoracostomy is placed.

The definitive treatment of any pneumothorax or hemothorax is tube thoracostomy. Rarely, operative exploration is performed to manage the pulmonary injury or source of hemorrhage. Multiple studies have confirmed that a 14 French thoracic catheter is equally effective as larger tubes for definitive treatment of pneumothorax with an added benefit of decreased pain. If the clinician has adequate expertise, tube insertion with ultrasound guidance may assist with confirming appropriate placement. The clinician uses the method with which they can most quickly, safely, and reliably relieve a pneumothorax.

■ Figure 5-11: Locations for Emergent Needle Thoracostomy.
Two consensus optimal locations for safe and effective needle decompression are indicated by the stars. One is between the anterior (AAL) and mid axillary (MAL) lines at the inframammary fold (IMF) level and the other is in the second intercostal space at the midclavicular line (MCL).



ASYMPTOMATIC AND OCCULT PNEUMOTHORAX MANAGEMENT

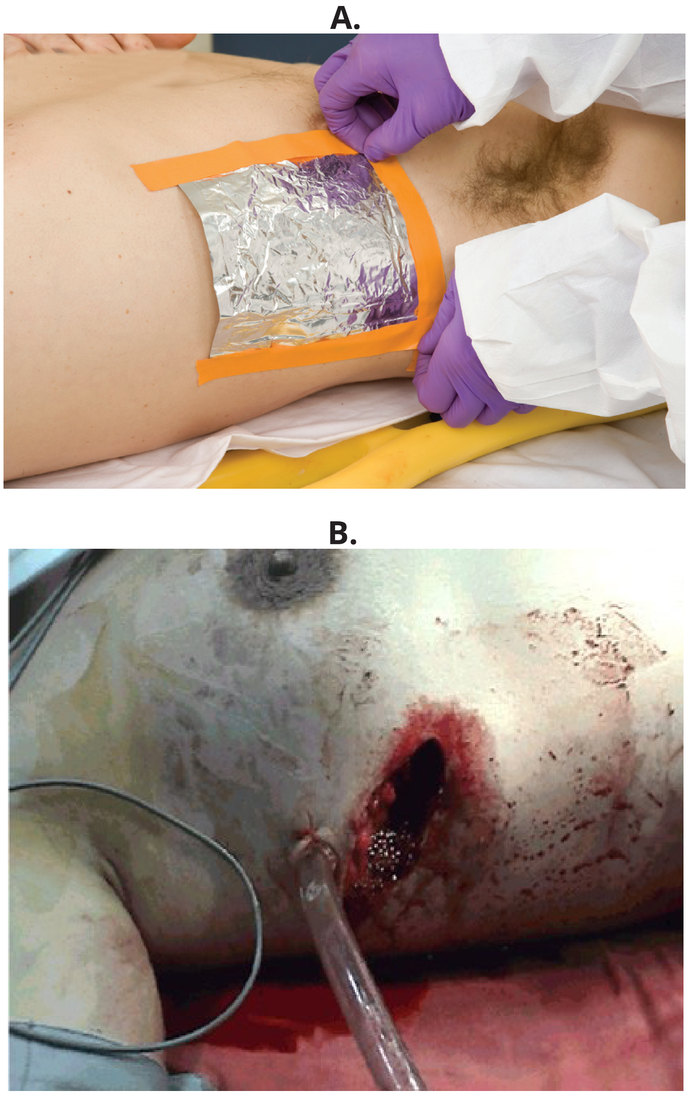
Treatment of asymptomatic pneumothorax is variable. Many trauma surgeons place chest tubes for asymptomatic, but CXR-visible, pneumothoraces unless the pneumothorax is very small. Recent studies suggest that asymptomatic pneumothoraces less than 3.5 cm from the chest wall, as measured on the CT scan, can be managed without tube thoracostomy. Failure of a non-tube strategy is associated with positive-pressure ventilation, more severe chest injury, and concurrent hemothorax.

Increasing size of a pneumothorax on serial CXR is an indication for chest tube placement. **In scenarios of clinically occult pneumothorax and planned transfer by air, the sending physician should discuss the need for chest tube insertion prior to transfer with the receiving physician.** The change in transpleural pressure with altitude can potentially result in enlargement of the pneumothorax and conversion from asymptomatic to symptomatic during flight.

OPEN PNEUMOTHORAX MANAGEMENT

Initial management of an open pneumothorax involves prompt coverage of the defect with a sterile dressing large enough to overlap the wound edges. Any occlusive dressing or a vented chest seal may be used as a temporizing measure. An occlusive dressing is taped securely to three sides to create a valve effect to prevent development of tension physiology. During inspiration, the dressing occludes the wound. On exhalation, the open side of the dressing allows air to escape. A tube thoracostomy is inserted through a separate incision as soon as feasible. Definitive therapy involves operative closure of the chest wall laceration with placement of a tube thoracostomy. **■ Figure 5-12** illustrates emergent management of an open pneumothorax.

■ Figure 5-12: Open Pneumothorax Management. A. A sterile occlusive dressing is placed to cover the wound. The dressing is secured on three sides to create a valve effect, preventing air entry with inhalation and allowing air to escape with exhalation. Alternatively, several commercial products are available which have an included valve. **B.** A tube thoracostomy is performed prior to operative repair.



HEMOTHORAX MANAGEMENT

Hemothoraces with estimated volume more than 300 mL are recommended to be evacuated using a tube thoracostomy to prevent the blood from congealing and creating a trapped lung. Accurate quantification of fluid volume is challenging in the emergent situation. **Thus, most traumatic hemothoraces are treated with tube thoracostomy. Massive whole-chest hemothorax may produce tension physiology and is treated with finger, followed by tube, thoracostomy.** As with pneumothorax, multiple studies have confirmed that a 14 French catheter is equally effective as larger tubes for definitive treatment of hemothorax. However, most of these studies excluded patients with massive or tension hemothorax, which is often treated with a larger-bore (≥ 24 French) tube.

Operative intervention for hemorrhage control may be indicated for tension or massive hemothorax. Emergency transfusion is common. **Operative decisions are based on physiologic status (e.g., shock) and continued bleeding** rather than specific initial or subsequent chest tube output. Some trauma center data suggest reduced rates of retained hemothorax and delayed surgery by employing a chest tube irrigation protocol once bleeding is controlled.

RIB FRACTURES AND FLAIL CHEST MANAGEMENT

The most common cause of morbidity and mortality after rib fractures is pneumonia due to pain precluding appropriate pulmonary hygiene. Thus, the treatment of rib fractures is based on pain control and ensuring appropriate pulmonary hygiene. Chest physiotherapy, incentive spirometry, and other modalities to promote alveolar expansion and pulmonary hygiene are critical. Intubation may be indicated when flail chest and chest wall instability cause inability to breathe, when severe underlying pulmonary contusion results in hypoxia, or when sedating medications are administered to provide appropriate pain relief.

A triage algorithm helps determine benefits of inpatient versus outpatient management and admission location (e.g., ICU versus ward). Protocols based on patient demographics and severity of injury are beneficial to ensure appropriate pain relief, pulmonary therapy, and monitoring. **Pain relief uses multimodal oral and IV medications, with emphasis on nonopioid therapies and locoregional pain control.** Multimodal pain relief can consist of acetaminophen/paracetamol, nonsteroidal anti-inflammatory drugs (NSAIDs), ketamine, lidocaine, and regional pain blocks. Surgical stabilization of rib fractures is effective in mitigating morbidity for select flail chest injuries.

DIAPHRAGM INJURY MANAGEMENT

Left diaphragm injuries are operatively repaired urgently. Chest tube insertion to treat concomitant hemothorax or pneumothorax may inadvertently injure herniated abdominal contents; thus, careful attention to safe placement is recommended. Diaphragmatic injuries with abdominal viscera herniated into the chest are immediately operatively repaired due to the risk of visceral strangulation. A transabdominal approach is elected most often. However, a transthoracic approach may be used in select instances based on the specific injury pattern. Selected right diaphragm injuries can be managed nonoperatively unless there is a concomitant liver injury. In this instance, diaphragm repair is considered to decrease the development of a biliopleural fistula.

TRACHEOBRONCHIAL INJURY MANAGEMENT

A tube thoracostomy is performed emergently, often preceded by needle or finger thoracostomy for treatment of tension pneumothorax. **Intubation of patients with tracheobronchial injury may be difficult because of anatomic distortion from surrounding trauma. Advanced airway skills, such as fiber optic-assisted endotracheal tube advancement distal to the tear or selective intubation of the unaffected bronchus, may be indicated. Surgical consultation is obtained immediately.** Small injuries may be amenable to nonoperative management. However, larger tears are operatively repaired. Placement of additional chest tubes may adequately control the leak and allow lung expansion.

REASSESSMENT

Patients are reassessed after each intervention using the initial evaluation approach of *"look, listen, feel."* Treatment adjuncts, such as tube thoracostomy, are evaluated to ensure proper function. Continuous pulse oximetry and capnography (when available) is performed to monitor appropriate gas exchange. Pain relief and the ability to cough and take deep breaths is assessed frequently for patients with rib fractures, as inadequate treatment can lead to pneumonia and respiratory failure.

TRANSFER CONSIDERATIONS

Patients with moderate and severe thoracic injury benefit from transfer to a trauma center. This includes patients for whom operative intervention is not planned but who will benefit from the resources of a trauma center. For example, patients with multiple rib fractures or flail chest (radiographic or clinical) benefit from the regional analgesia, physiotherapy, and possible surgical stabilization services that a trauma center offers. However, **the most common invasive intervention following thoracic trauma is tube thoracostomy. This is a potentially lifesaving procedure that is completed prior to transfer,** particularly for symptomatic patients prior to transport by air or by a medical crew that is not credentialed or equipped to perform emergent chest decompression. Chest tubes are maintained at –20 cm H_2O suction during transport.

SPECIAL POPULATION CONSIDERATIONS

Late-term pregnant patients have specific considerations. The gravid uterus will prevent full movement of the diaphragm, thereby resulting in small lung volumes. A higher diaphragm is considered when placing a needle, finger, or tube thoracostomy. Adjusting chest entry cephalad by 1–2 rib spaces may be beneficial. The second intercostal space at the midclavicular line may be a preferred site for needle thoracostomy.

Children have a smaller torso. The clinician performs the needle, finger, or tube thoracostomy at or slightly superior to the IMF. Smaller tubes are indicated due to a smaller intercostal space. **Because of greater chest wall pliability, children are at greater risk of sustaining and developing a pulmonary contusion in the absence of rib fractures compared to adults.**

Frail and older adult patients are at higher risk of deleterious outcomes after chest wall injury and are likely to benefit from structured care pathways and referral center management.

Obese patients have unique considerations for thoracostomy. Penetration of the pleura is less likely to be successful with a short needle thoracostomy. A sufficiently long catheter or a finger thoracostomy is used instead. A tube thoracostomy can also be challenging. Successful placement may be accomplished through a larger incision, which permits dissection to the ribs and placement of an intrapleural tube.

PRACTICE ENVIRONMENT CONSIDERATIONS

When CT scan is not readily available, ultrasound and x-ray (in combination or individually) can be used to assess for most thoracic injuries. A limitation of not having a CT scan is evaluation of the aorta and great vessels. Ultrasound as an imaging modality has the advantages of bedside performance on a supine patient, repeatability, noninvasiveness, lack of radiation, and ability to detect a variety of thoracic pathologies, including pneumothorax, hemothorax, and pulmonary contusion.

A pulmonary contusion may be diagnosed by the presence of an irregularly outlined, moderately hypoechoic lesion or hyperechoic punctate images corresponding to an air bronchogram. There may be multiple B-lines. Ultrasound has the disadvantage of being operator dependent, with specialized training being desirable to create and interpret images.

In instances where a chest tube is not readily available, other tubes (e.g., endotracheal tube) can be used to decompress the pleural space. The endotracheal tube balloon may be inflated and used to anchor the tube in the chest cavity.

CHAPTER SUMMARY

Thoracic injury is very common. Rapid and organized assessment is critical to detect life-threatening problems. Most injuries can be diagnosed with physical exam, CXR, and ultrasound, although CT scan provides much more detailed information. The most common intervention is chest cavity decompression via needle, finger, or tube thoracostomy. Emergency or urgent thoracotomy is rare. Expeditious transfer to a trauma center capable of providing a higher level of respiratory support and potential operative intervention is beneficial, particularly for more frail and critically ill patients.

KEY LEARNING POINTS

- **Chest injury is common following both blunt and penetrating trauma.**
- **Breathing is impaired following chest injury due to altered oxygenation, ventilation, and hemorrhage.**
- **Assessment for chest injury utilizes a "look, listen, and feel" approach, oximetry, chest radiographs, and other adjuncts.**
- **Presumptive administration of supplemental oxygen for injured patients is beneficial until breathing status is assessed and managed.**
- **The most common lifesaving emergent intervention following thoracic trauma is chest decompression via needle, finger, or tube thoracostomy. These are important skills for the trauma clinician to master.**
- **A multimodal approach is employed to manage pain associated with chest wall injury.**
- **Operative decisions are based primarily on physiologic status.**
- **Regardless of potential for operative intervention, patients with moderate to severe thoracic injury benefit from transfer to a trauma center.**
- **Older and frail patients are at high risk of complications following even minor chest injury and benefit from trauma center management.**

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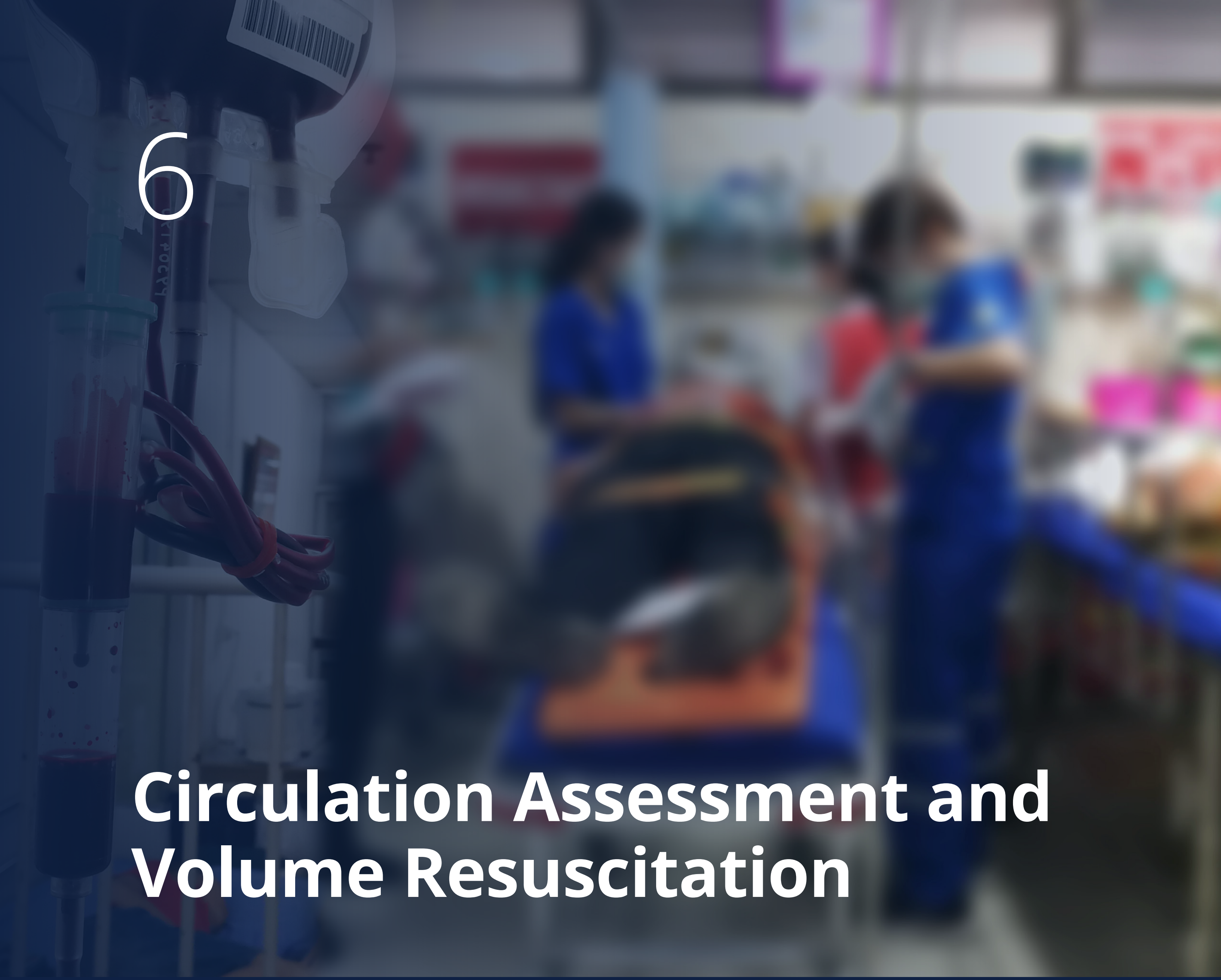


6

Circulation Assessment and Volume Resuscitation

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Identify shock in a trauma patient
2. Recognize significant blood loss with resultant decreased intravascular volume in a trauma case
3. Address circulation abnormalities at the appropriate stage of the primary survey
4. Initiate resuscitation for shock
5. Evaluate the cause of shock in a trauma patient
6. Reassess and alter resuscitation strategy based on patient responses to resuscitation
7. Recognize limitations of the local practice environment, resources for optimal management, and the role of transfer in a trauma scenario

6

Circulation Assessment and Volume Resuscitation

CHAPTER STATEMENT

Identifying and promptly addressing circulatory compromise, or shock, in trauma patients is crucial for achieving successful outcomes. As no single test can diagnose shock, a combination of clinical assessment, recognition of altered physiology, and use of appropriate adjuncts is essential. The cornerstone of shock management is to identify its underlying cause. While hemorrhage is the most common cause in trauma, it is imperative to exclude other causes such as obstructive, cardiogenic, and distributive.

INTRODUCTION

Circulatory compromise in trauma patients can result from a variety of injuries and generally manifests as shock. **Management of shock in trauma patients involves prompt recognition and appropriate resuscitation.** A more precise diagnosis of the cause of shock allows treatment to be adjusted. **Shock is defined as insufficient tissue perfusion and oxygenation.** Without prompt diagnosis and management, shock severity can rapidly escalate, leading to organ dysfunction and mortality.

PATHOPHYSIOLOGY

GENERAL

The lack of adequate tissue circulation prevents optimal cellular energy metabolism, which normally powers all bodily functions. Shock in trauma patients can be classified into two large categories, hemorrhagic or nonhemorrhagic. **Hemorrhage is the most common cause of shock in the injured patient.** Trauma patients often endure significant blood loss culminating in hypovolemic, hemorrhagic shock. **Early recognition of blood loss allows healthcare clinicians to promptly initiate suitable resuscitation measures, such as hemorrhage control and blood transfusion, to restore circulating volume and prevent further deterioration.** Nonhemorrhagic shock can be further classified into obstructive (e.g., cardiac tamponade or tension pneumothorax), cardiogenic (e.g., blunt cardiac injury), or distributive (e.g., neurogenic or septic) etiologies. Each type of shock necessitates specific interventions and management approaches, ■ **Table 6-1** lists three classifications of nonhemorrhagic shock and their associated etiologies.

■ **Table 6-1. Three Types of Nonhemorrhagic Shock.**

Classification of Nonhemorrhagic Shock in Trauma Patients

Type of Shock	Trauma Etiologies
Obstructive	Tension pneumothorax Cardiac tamponade
Cardiac	Blunt cardiac injury Myocardial infarction
Distributive	Neurogenic Septic Anaphylactic

HYPOVOLEMIC/HEMORRHAGIC SHOCK

Hemorrhage is the most common cause of shock in trauma patients. Recognizing significant bleeding with subsequent loss of intravascular volume is crucial. Hemorrhage is defined as an acute blood loss from circulating volume. Normal adult blood volume is approximately 7% of body weight, although it can vary considerably. For example, a 70 kg patient has a circulating blood volume of approximately 5 L. The blood volume of patients with a higher proportion of adipose tissue is estimated based on ideal body weight. Calculation based on the actual weight of these patients can result in significant volume overestimation. For pediatric patients, total circulating blood volume can be estimated as 80 mL/kg for an infant, 75 mL/kg at ages 1-to-3 years, and 70 mL/kg after age three.

The clinical signs of hypovolemic shock are directly related to the dysfunction of each organ system and to physiologic compensation, both detectable and occult. ■ **Table 6-2** illustrates changes in several parameters as hemorrhage severity increases. Initial physiologic adjustments to blood loss include progressive vasoconstriction of cutaneous, muscular, and visceral circulation to preserve blood flow to more vital organs. **Tachycardia is the earliest measurable sign of hypovolemia.** Heart rate increases to preserve cardiac output. Narrowing of pulse pressure and hypotension occur after moderate to severe blood loss. The release of endogenous catecholamines increases peripheral vascular resistance, which increases diastolic blood pressure and reduces pulse pressure. However, this does little to increase organ perfusion and tissue oxygenation.

Blood loss produces peripheral vasoconstriction, resulting in cool and clammy skin. The body redistributes blood flow to vital organs, sacrificing peripheral perfusion. **An injured patient with cool skin and tachycardia is in shock until proven otherwise.** Paleness of mucous membranes (inner eyelids, conjunctiva, oral mucosa, tongue, and lips) can be a sign of reduced blood volume. In lightly pigmented individuals, the skin may appear pale.

Shivering and inability to maintain core temperature are a direct consequence of shock. **Anxiety is an early sign and may progress to agitation and confusion.** Lethargy and decreased level of consciousness follow as shock severity increases, even in

■ **Table 6-2. Changes in Clinical Parameters as Related to Hemorrhage Severity.** Response to blood loss varies based on patient factors and source control. Response to resuscitation is dependent on the presence of continued bleeding, not on a specific volume of blood loss.

	HEMORRHAGE SEVERITY →			
PARAMETER	**MINOR**		**MODERATE**	**MAJOR**
Heart Rate (beats/min)	Unchanged	Unchanged to Increased	Increased (>100)	Markedly Increased (>120)
Systolic Pressure (mm Hg)	Unchanged	Unchanged	Unchanged to Decreased	Markedly Decreased (<90)
Pulse Pressure	Unchanged	Decreased	Decreased	Decreased
Respiratory Rate	Unchanged	Unchanged to Increased	Increased	Increased
Level of Consciousness	Unchanged	Unchanged	Decreased	Markedly Decreased
Base Deficit (meq/L)	0 to -2	-2 to -6	-6 to -10	-10 and less
Blood Products	Unlikely	Possibly	Likely	Massive Transfusion Protocol
Response to Resuscitation	Rapid and Sustained	Fairly Rapid and Sustained	Transient	Minimal to None
Operative Hemorrhage Control	Unlikely	Possibly	Likely	Extremely Likely

the absence of primary central nervous system injury. Patients experiencing significant blood loss often report thirst as the body attempts to compensate for fluid loss.

As blood volume decreases, the body compensates by increasing the respiratory rate to improve oxygenation and correct metabolic acidemia through respiratory alkalosis. Tachypnea can be an early sign of significant blood loss. In response to hypovolemia, the body attempts to conserve fluid by reducing urine output. Monitoring urine output over time is helpful in recognizing continued hypovolemia. A decrease in urine output (i.e., oliguria) may indicate inadequate circulating volume. However, recognition of decreased urine output takes time and will not be able to be identified during initial assessments.

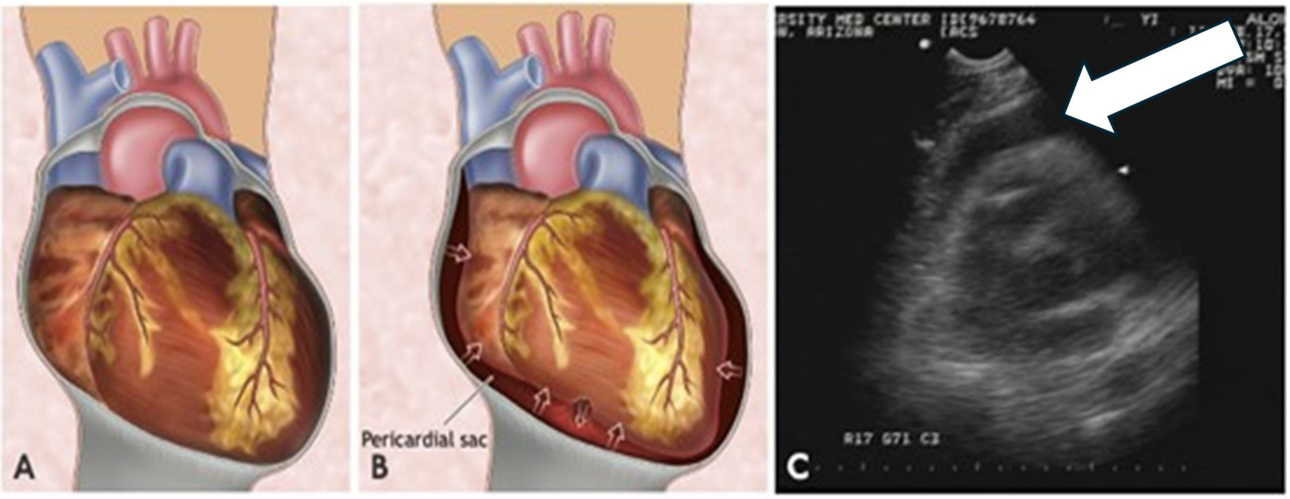
When the compensatory mechanisms of tachycardia and increased peripheral vascular resistance are exhausted, hypotension will occur, further compromising all organ functions. When near-complete energetic failure is imminent, bradycardia with circulatory collapse occurs.

OBSTRUCTIVE SHOCK

Obstructive shock refers to compromised cardiac output due to hindered cardiac preload. **Two common trauma-associated diagnoses are tension pneumothorax and cardiac tamponade.** Both conditions can rapidly lead to circulatory arrest without significant blood loss due to insufficient cardiac venous return.

Tension pneumothorax is discussed in *Chapter 5, Breathing and Ventilation Assessment and Management.* Air enters the pleural space but does not escape. Intrapleural pressure rises, eventually collapsing the entire lung on the affected side. Increasing pressure shifts the mediastinum to the opposite side. Higher mediastinal pressure impedes caval blood flow and venous return. Cardiac output decreases. This process is lethal unless prompt intervention is performed. Please see *Chapter 5, Breathing and Ventilation Assessment and Management,* **Figure 5-3** for an illustration of the pathophysiology of tension pneumothorax.

Cardiac tamponade is more common following penetrating rather than blunt trauma. Cardiac tamponade is a life-threatening condition where fluid accumulates in the pericardial sac, compressing the chambers of the heart. The lower-pressure atria are unable to relax. Similar to tension pneumothorax pathophysiology, venous return, preload, and subsequently cardiac output are reduced. Untreated, this process is fatal. Even with treatment, mortality remains high. ■ **Figure 6-1** illustrates cardiac tamponade.



■ Figure 6-1: Cardiac Tamponade.
A. Normal heart. **B.** Following penetrating or blunt injuries, cardiac tamponade can develop as the pericardium fills with blood from the heart, great vessels, or pericardial vessels. **C.** Ultrasound image showing pericardial fluid in a patient with tamponade physiology.

CARDIOGENIC SHOCK

Blunt cardiac injury (BCI) is most frequently encountered after motor vehicle crashes and pedestrians struck by motor vehicles. Other mechanisms include falls, crush injuries, assaults, and sports-related direct blows to the chest. Blunt trauma can result in myocardial muscle contusion, cardiac chamber rupture, coronary artery thrombosis or dissection, and valvular disruption. The right atrium is the most likely chamber to be injured, followed by the right ventricle, and, less likely, the left heart. BCI may produce a range of abnormalities from asymptomatic mild arrhythmias to lethal cardiac failure. In older patients, ischemic cardiac events may precede or even be the cause of the traumatic event (e.g., falls and motor vehicle crashes).

DISTRIBUTIVE SHOCK

The most common mechanism of distributive shock in a trauma patient is spinal cord injury. Neurogenic shock may occur after cervical or high thoracic spinal cord injuries. Hypotension occurs from loss of efferent sympathetic signals from the spinal cord, resulting in a decrease in peripheral vascular resistance. Anaphylactic and septic shock are rarer distributive types of shock in trauma patients. They may be related to an underlying event that caused the traumatic event. Anaphylactic shock may develop in response to treatment such as medication or blood product transfusions. Septic shock may be observed in patients with delayed presentations of a perforated viscus, pulmonary injury with pneumonia, urinary infection that precipitated the traumatic event, or contaminated open fracture. Such patients may be from remote locations or victims in natural or humanitarian disaster situations.

DIAGNOSING THE PRESENCE OF SHOCK

GENERAL

Early identification of shock facilitates targeted diagnostics and treatments for the underlying cause and enables appropriate resource allocation. Early activation of trauma teams and involvement of specialists like surgeons, anesthesiologists, and intensivists are crucial for effective shock management. Recognizing shock facilitates timely communication and mobilization of these resources, ensuring comprehensive care from the moment the patient arrives at the healthcare facility.

Patient outcomes are deleteriously affected by late recognition of shock. Studies consistently demonstrate that delayed recognition and treatment of shock are associated with heightened morbidity and mortality. Promptly identifying and initiating appropriate interventions can improve tissue perfusion, prevent organ dysfunction, and increase the likelihood of a favorable outcome. Timely identification enables early intervention, appropriate triage, targeted treatment, continuous monitoring, guided resource allocation, multidisciplinary collaboration, and the best possible chance of recovery and survival.

Diagnosing shock in a trauma patient relies on a synthesis of clinical findings and laboratory tests. No single vital sign or laboratory test, on its own, can definitively diagnose shock. The clinical signs of shock are directly related to the dysfunction of each organ system and their evident or occult compensatory mechanisms. Rapid detection of inadequate tissue perfusion by identifying common clinical indicators is paramount. Through early recognition of shock, clinicians can implement targeted treatments such as controlling bleeding, initiating volume resuscitation, alleviating cardiac tamponade, or relieving tension pneumothorax. Continuous assessment of vital signs, perfusion parameters, and laboratory values enables timely detection of deteriorating shock and recognition of inadequate response to treatment.

PHYSICAL EXAM

Continual monitoring of blood pressure and heart rate is essential both to identify shock and to monitor treatment response. **However, relying solely on systolic blood pressure as an indicator of shock can delay recognition, as compensatory mechanisms can prevent a measurable fall in systolic pressure** until a significant amount of the blood volume is lost. In most adults, tachycardia and cutaneous vasoconstriction are the initial physiologic responses to volume loss. Heart rate divided by systolic blood pressure, known as shock index (SI), may assist in early recognition of hypoperfusion. A normal SI is ≤ 0.7. SI ≥ 1 is correlated with higher mortality. SI ≥ 0.8 is correlated with blood product transfusion, emergent surgical therapy, increased 24-hour and in-hospital mortality, and increased ICU and hospital lengths of stay.

Reduced blood volume can result in weakened peripheral pulses. Palpating peripheral pulses, such as the radial or dorsalis pedis, can help determine the strength and quality of blood flow to the extremities. Weak or thready pulses suggest compromised perfusion due to blood loss. Since $ETCO_2$ reflects pulmonary perfusion, a low $ETCO_2$ reading may also be indicative of shock. Monitoring of other parameters such as capillary refill time, urine output, lactate levels, and base deficit assists with informed decisions regarding transfusion, volume administration, and other interventions. In shock, the brain may not receive adequate oxygen and nutrients, resulting in mental status changes. Patients may exhibit a range of alterations, from confusion and agitation to somnolence and loss of consciousness.

LABORATORY VALUES

Complete blood count, coagulation profile, ABG analysis, and serum lactate levels provide valuable information regarding hemodynamic status and potential etiology of shock. Serial measurements of hemoglobin, hematocrit, and acid-base status can aid in assessing blood loss over time. However, a normal initial hematocrit or hemoglobin does not exclude significant hemorrhage. Ongoing shock leads to poor tissue perfusion with increased anaerobic metabolism and lactic/metabolic acidosis. Initial measurement of serum lactic acid level and/or base deficit can aid in identification of shock. Serial measurements can help guide treatment. A significant decline in these values may indicate continued shock and spur further intervention.

CLINICAL JUDGMENT

Judgment is vital to placing clinical findings in context and recognizing shock. Decision-making is guided by assessment of the overall clinical scenario, including mechanism of injury, presence of penetrating wounds, potential for spine injury, and other factors. Blood loss may be visible or occult, with the latter being more challenging to identify. Signs and symptoms may vary depending on the patient's age, comorbidities, and compensatory mechanisms. Therefore, healthcare clinicians consider the entire clinical context when evaluating a trauma patient for shock.

ASSESSMENT

DETERMINING THE SOURCE OF SHOCK

Identifying the underlying etiology of shock allows for targeted interventions and optimal outcomes. Once shock is diagnosed or suspected, resuscitation is initiated while an evaluation for the source is simultaneously performed. The presence of shock in a trauma patient is an indication to immediately consider consultation of a surgeon and other specialists, if available, or to consider transfer to a center with appropriate resources. To recognize and manage hemorrhagic and nonhemorrhagic forms of shock, clinicians remain alert to the patient's status and carefully observe the response to treatment.

HISTORY

The mechanism (e.g., motor vehicle, fall, crush, thermal, penetrating) and forces (car versus bicycle, height of fall, firearm or cutting instrument) related to injury are obtained from the patient, witnesses, or prehospital personnel. A prehospital report of mechanism, potential injuries, vital signs, and treatments and responses will alert the clinician to potential diagnoses and causes of shock.

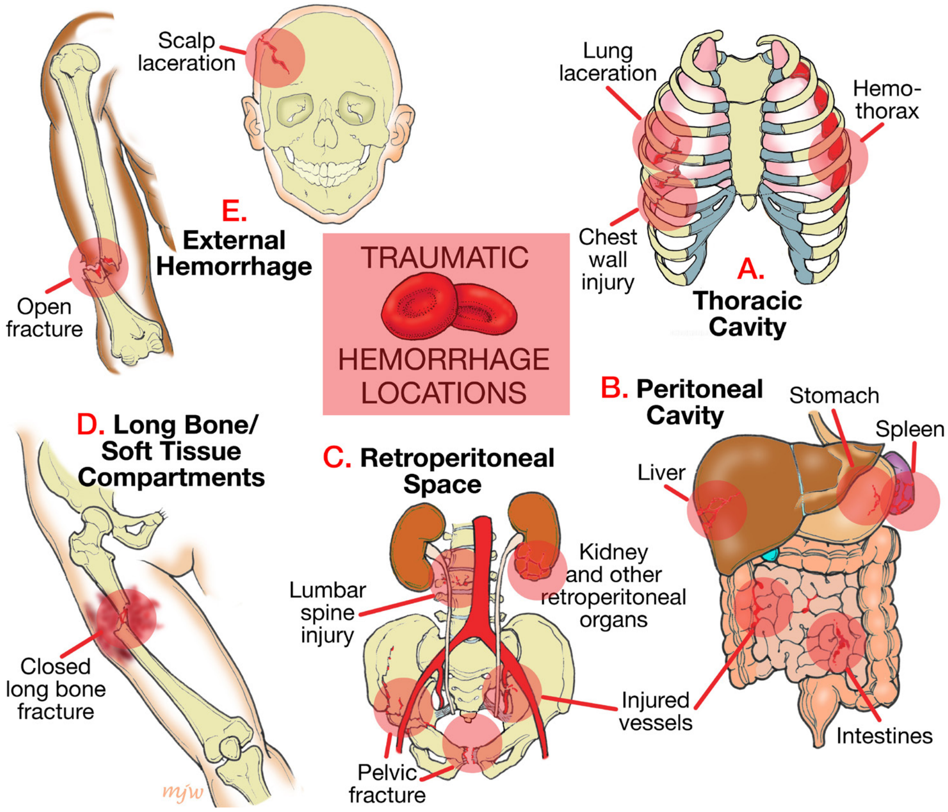
The physiologic impact of all shock is magnified in the presence of preinjury medications. Knowledge of the patient's medical history is vital, particularly regarding therapy that alters blood coagulation (anticoagulant and antiplatelet therapy), blood pressure regulation (antihypertensive medications), and heart rate compensation (beta blockers). For unconscious patients, prehospital clinicians make a diligent search for medication bottles, lists (on devices or in wallets), and pharmacy and family contacts.

As hemorrhage is the most common etiology of shock in an injured patient, the clinician assumes the presence of continuing hemorrhage. The sayings "one on the floor and four more" or "four and the floor" assist in recall of potential locations for life-threatening hemorrhage. "Four" refers to anatomic locations of major internal hemorrhage (chest, abdomen, pelvis, and long bone/intramuscular), and "floor" refers to external hemorrhage (blood on the floor). These sites are evaluated during the primary survey. ■ **Figure 6-2** illustrates five sites of major hemorrhage.

PRIMARY SURVEY

The primary survey utilizes the xABCDE steps of ATLS. Before reaching the "Circulation" evaluation and as described in earlier chapters, the clinician has previously addressed "x" by controlling visible compressible exsanguinating external hemorrhage ("the floor") and "A" by ensuring the airway has been opened and maintained. Oxygen administration, when available, has been initiated. Other team members have placed cardiac, oxygen saturation, and $ETCO_2$ monitors if available. If not previously obtained, large-bore IV or intraosseous access is obtained while assessment is performed.

■ Figure 6-2: Potential Anatomic Locations for Blood Loss, "One on the Floor and Four More" or "Four and the Floor". A. Thoracic cavity. **B.** Peritoneal cavity. **C.** Pelvic and Retroperitoneal Space. **D.** Long bone fracture sites, muscle compartments, and subcutaneous tissue. **E.** External hemorrhage ("the floor").


Scalp laceration
E. External Hemorrhage
Open fracture
TRAUMATIC HEMORRHAGE LOCATIONS
Lung laceration
Hemo-thorax
Chest wall injury
A. Thoracic Cavity
B. Peritoneal Cavity
Stomach
Spleen
Liver
D. Long Bone/ Soft Tissue Compartments
C. Retroperitoneal Space
Kidney and other retroperitoneal organs
Lumbar spine injury
Closed long bone fracture
Injured vessels
Intestines
Pelvic fracture
mjw

Recognized at the "Breathing" stage of the primary survey, tension pneumothorax is a nonhemorrhagic cause of obstructive shock and a clinical diagnosis. The presentation is acute respiratory distress, absent unilateral breath sounds, hyperresonance to percussion (difficult to hear in the emergency department), and tracheal shift away from affected side (often subtly recognized at the sternal notch). Emergent release of the pneumothorax (see *Chapter 5, Breathing and Ventilation Assessment and Management*) is performed without waiting for radiographic or other diagnostic confirmation.

During "Circulation" evaluation, an expeditious examination is performed, focused on detecting signs and locations of internal bleeding. Thoracic evaluation may reveal tenderness from rib fractures, a flail segment, a wound, decreased breath sounds, ecchymosis (potentially related to a shoulder restraint or airbag), or dullness to percussion (hard to appreciate in an emergency department). These signs are consistent with hemothorax.

Another nonhemorrhagic cause of obstructive shock diagnosed during the primary thoracic evaluation is cardiac tamponade. **The typical clinical presentation of cardiac tamponade includes an appropriate mechanism (e.g., penetrating chest trauma), tachycardia, and hypotension that is unresponsive to fluid therapy.** Muffled heart sounds and dilated, engorged neck veins may be present. However, these signs are difficult to appreciate in the emergency department. The absence of classic findings does not exclude cardiac tamponade (see Imaging and Diagnostic Studies).

Abdominal distension, tenderness, penetrating wounds, and ecchymosis may indicate intra-abdominal hemorrhage. Suprapubic tenderness, a widened pubic symphysis, tenderness on the pelvic bones, external rotation of the hips, perineal bruising, and urethral meatal blood are signs of potential pelvic fracture with associated pelvic cavity/retroperitoneal hemorrhage. Major pelvic fractures and associated retroperitoneal hematomas can produce several liters of blood loss, which is potentially lethal.

Palpation and visual examination of all extremities is performed for tenderness, wounds, contusions, swelling, and instability. Long bone extremity fractures may result in significant blood loss. Each closed tibia or humerus fracture can result in up to 750 mL of blood loss, and a closed femur fracture can result in up to 1.5 L of hemorrhage. Thus, multiple extremity fractures can be a source of lethal hemorrhage.

Major soft-tissue injuries can account for significant blood loss, either through bleeding or associated edema (third-space fluid loss). Massive contusions and hemorrhagic shock can occur in patients receiving preinjury anticoagulation therapy. Occasionally, "minor" injuries, such as a scalp wound or a penetrating extremity injury, can cause significant delayed external bleeding not initially evident upon arrival, which may contribute to hemorrhagic shock. Edema occurs with major soft-tissue injury and is another source of volume loss. Tissue injury, even without significant blood loss, can lead to release of multiple cytokines, which increase endothelial cell vascular permeability, producing a fluid shift from plasma to the extracellular space, which further depletes intravascular volume and exacerbates shock.

History and physical examination may reveal signs consistent with nonhemorrhagic shock. Cardiac tamponade and tension pneumothorax have been discussed previously. **The clinical signs of neurogenic shock include hypotension, bradycardia, paralysis, numbness, paresthesia, loss of rectal tone, and warm peripheral extremities. These are in contrast to hemorrhagic shock, which presents with tachycardia and peripheral vasoconstriction, which causes cool skin.** Diagnosis can be difficult in unconscious patients without a detectable neurological deficit. The term *neurogenic shock* is often confused with the term *spinal shock*. Spinal shock refers to the lack of function of the spinal cord after injury that may recover. Spinal and neurogenic shock can present simultaneously.

Potential etiologies of cardiogenic shock in an injured patient include BCI and acute myocardial infarction (AMI). Patients with BCI may be asymptomatic or may complain of common symptoms such as chest pain or shortness of breath associated with detectable tachypnea. Tenderness, abrasions, and contusions ("seatbelt sign" across the chest) may be present on the thoracic wall and/or sternum. A variety of arrhythmias may be present. As signs are nonspecific, the clinical context is important to consider in the diagnosis. AMI, consequent to or as a cause of the injury, presents similarly to nontraumatic AMI. Following trauma, AMI is considered after other shock etiologies have been evaluated and managed.

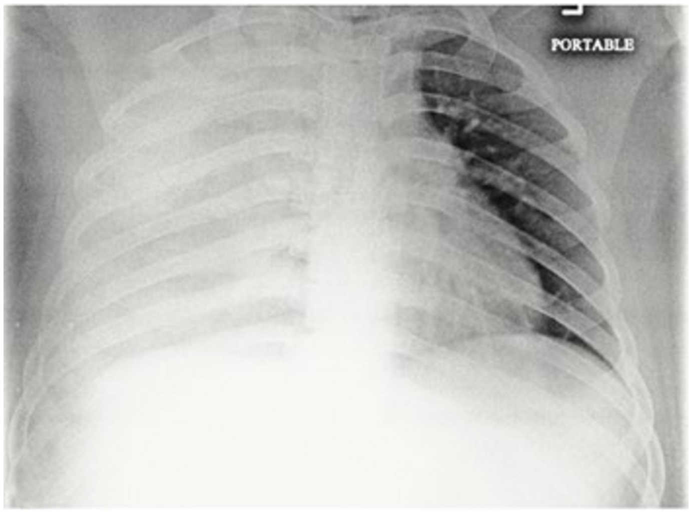
Signs of posttrauma anaphylactic and septic shock are similar to those of nontrauma etiologies. Clinical context, history, and exclusion of hemorrhage are important for diagnosis. As mentioned earlier, sepsis may have been present preinjury (e.g., frequent in older patients who fall) or be the result of delayed presentation. A history of medication or transfusion may assist with diagnosis of anaphylactic shock.

IMAGING AND DIAGNOSTIC STUDIES

Various imaging and other studies may be performed to diagnose the source of shock in a trauma scenario. **However, treatment of shock and bleeding is not delayed to perform confirmatory studies. When clinically indicated, emergent interventions prior to proof of diagnosis may be lifesaving (e.g., control of external bleeding, blood product [or fluid if blood not available] resuscitation, chest decompression, or application of a pelvic compression device).**

CXR, pelvic radiograph (PXR), and FAST/DPL can be used to determine the source of shock, guide management, and monitor responses to treatments. CXR may confirm hemothorax, demonstrate findings consistent with pericardial fluid, or confirm appropriate result following thoracic decompression. ■ **Figure 6-3** illustrates a CXR with massive hemothorax. PXR may define a pelvic fracture and appropriate result following placement of a temporary pelvic compression device.

■ Figure 6-3: Chest Radiograph with Massive Hemothorax.



Point-of-care abdominal ultrasound (e.g., FAST) may demonstrate intra-abdominal fluid. ■ **Figure 6-4** illustrates FAST probe positions and a FAST image. Diagnostic peritoneal lavage (DPL) is utilized instead of FAST in some locations. DPL is further discussed in *Chapter 21, Thoracic, Abdominopelvic, and Genitourinary Trauma*. FAST evaluates for hemorrhage in the abdomen and pericardium while DPL only evaluates the abdomen. ■ **Figure 6-5** illustrates bloody fluid return during DPL. Although these studies are not therapeutic, the result may facilitate rapid surgical consultation and/or transfer.

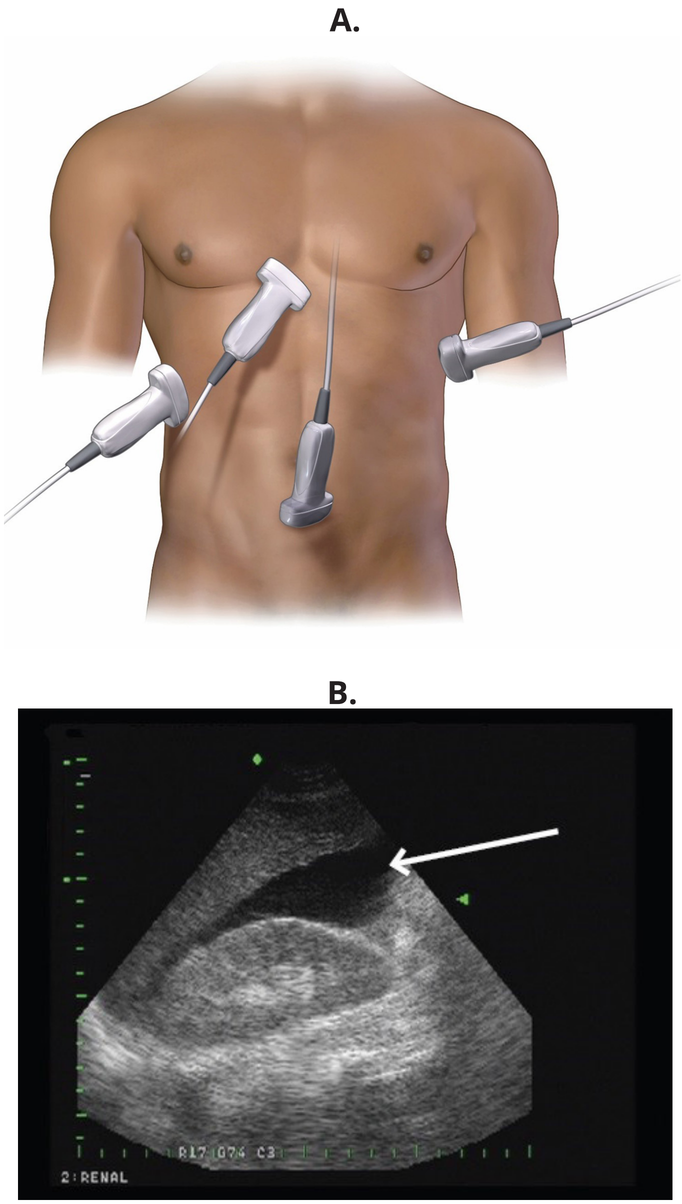
Extended FAST (eFAST) adds views of the thorax to evaluate for pneumothorax and hemothorax. FAST and echocardiography are extremely helpful for diagnosis of suspected cardiac tamponade. Significant resources, which may not be available at all centers, are utilized to manage cardiac tamponade. Therefore, rapid diagnosis may improve time to transfer and treatment.

In scenarios where a neurogenic etiology of shock is suspected (e.g., hypotension, bradycardia, warm extremity skin, paralysis), a lateral cervical spine radiograph may demonstrate an abnormality and facilitate transfer and/or involvement of a spine surgeon. **When neurogenic shock is present, evaluation and imaging for concurrent hemorrhage (CXR, PXR, FAST, DPL) is performed as well.**

BCI may present with a broad spectrum of symptoms and signs, from mild arrhythmias to cardiogenic shock. As these are nonspecific, when BCI or myocardial infarction is considered, a 12-lead ECG is obtained. ECG findings consistent with BCI include unexplained sinus tachycardia, premature ventricular contractions, atrial fibrillation, bundle branch block (more commonly right) and ST segment changes. However, a normal ECG at the time of presentation does not definitively exclude BCI. The role of cardiac biomarkers in evaluating and guiding management of patients with BCI has not been clearly established.

The most widely accepted biomarkers of shock severity and response to resuscitation are the base deficit (evaluated by blood gas analysis) and the lactate level. A linear or predictable

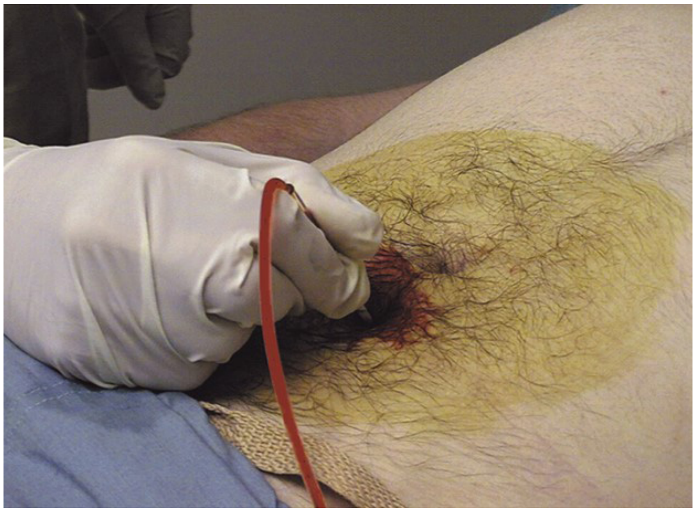
■ **Figure 6-4: Focused Assessment with Sonography for Trauma. A.** Probe locations. **B.** FAST image of the right upper quadrant showing the liver, kidney, and free fluid.



relationship between magnitude of blood loss and base deficit or lactate level does not exist, partly due to a multifactorial pathogenesis of hyperlactatemia in shock. However, increasing lactate and base-deficit levels correspond to decreased perfusion at the cellular level and are attributed to worsening shock until proven otherwise.

Evaluation of coagulation status is valuable to detect preinjury anticoagulant therapy and development of shock-induced altered thrombosis. Frequent values obtained are partial thromboplastin time (PTT), prothrombin time (PT), international normalized ratio (INR), and platelet count. In some institutions, viscoelastic testing may be available to more precisely evaluate the coagulation system.

■ **Figure 6-5: Diagnostic Peritoneal Lavage (DPL).** DPL is a rapidly performed, invasive procedure that is sensitive for the detection of intraperitoneal hemorrhage.



MANAGEMENT

GENERAL

Based on the mechanism of injury and clinical findings, specific etiologies of shock are identified to focus management. **Early hemorrhage control and restoration of circulating volume through appropriate fluid resuscitation are the goals of treatment of traumatic shock and are crucial to improved patient outcomes. Fluid administration (see below) is initiated as soon as signs and symptoms of blood loss are apparent or suspected, and is not delayed until blood pressure decreases or a specific diagnosis is finalized.**

The clinician continually observes and reassesses the patient during interventions, observing vital signs, oxygen saturation, urine output, $ETCO_2$ (if used), and mentation. The responses can provide important information about the underlying cause of shock. Multidisciplinary collaboration with available specialists such as surgeons, interventional radiologists, anesthesiologists, and intensivists early in the evaluation process can help guide further investigations and interventions, ensuring comprehensive care for the trauma patient.

CONTROL OF BLEEDING

The most effective methods of reestablishing adequate cardiac output, end-organ perfusion, and tissue oxygenation are to restore venous return through vascular volume repletion and to stop the bleeding. Volume repletion will allow recovery from the shock state only when the bleeding has stopped. Following the xABCDE steps, exsanguinating bleeding is controlled urgently with packing or a tourniquet if indicated. The airway is maintained. Tension pneumothorax is identified by clinical parameters and released. Hemothorax is identified by clinical exam and imaging, if available, and drained by tube thoracostomy.

■ **Table 6-3** lists clinical factors that are associated with pelvic fractures. When diagnosis of a pelvic fracture is supported by the clinical scenario, a pelvic compression device (also termed "pelvic binder") may be lifesaving. Technical components of appropriate placement include centering the device around the greater trochanters. Additional prevention of hip external rotation (if possible) helps to reduce potential pelvic volume and promote tamponade of pelvic vessels.

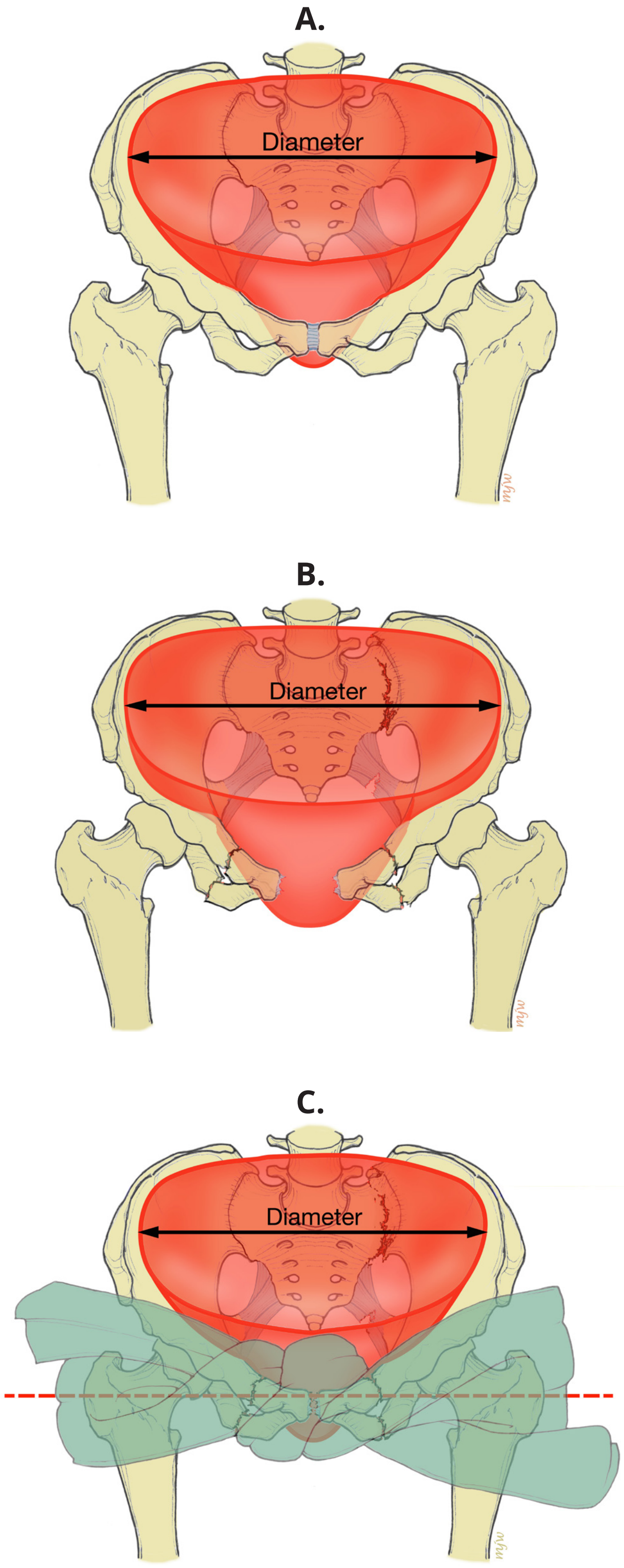
■ Table 6-3: Clinical Factors Associated with a Pelvic Fracture.

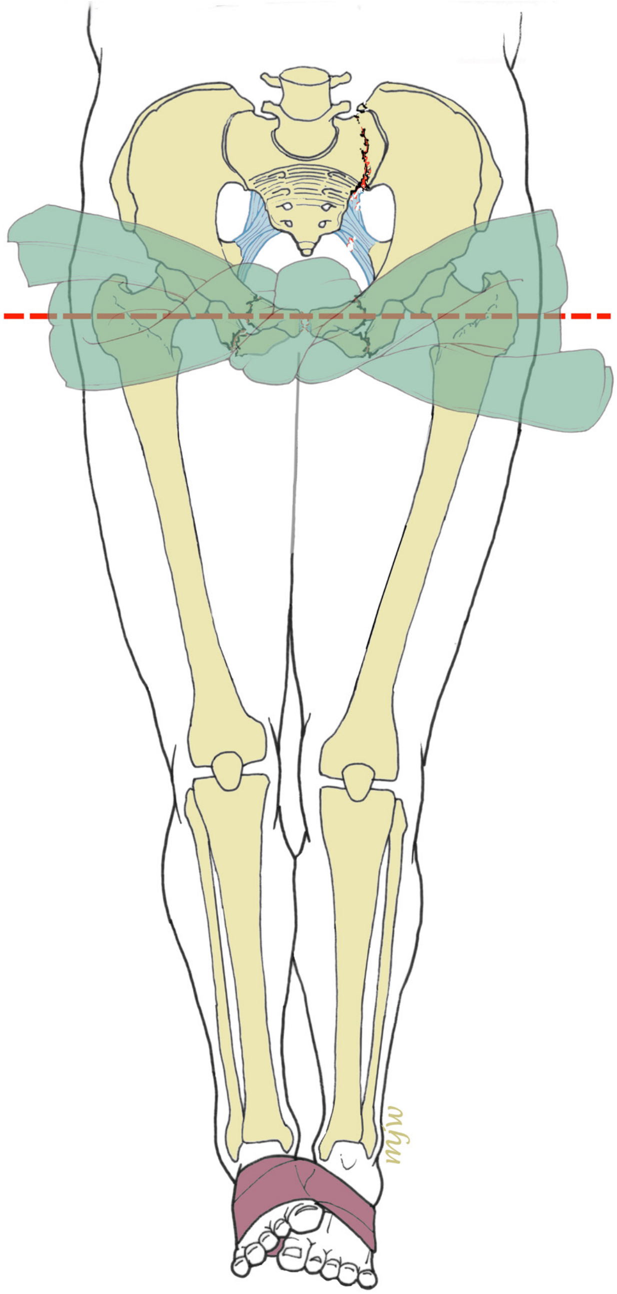
Clinical Data Consistent with Pelvic Fracture	
MECHANISM	Motor vehicle or motorcycle crash Fall from height Fall in frail patient Fall from animal transport Crush Bicycle crash
SYMPTOMS	Pelvic pain Low abdominal pain Hip pain Pain radiating in lower extremities Low back pain
SIGNS	Hypotension, tachycardia Pain on palpation of pelvis Lower abdominal tenderness Pain with hip movement External rotation lower extremities Sacral/coccyx tenderness Suprapubic widening Suprapubic, iliac ecchymosis Perineal ecchymosis Blood at urethral meatus Vaginal blood

■ **Figure 6-6** illustrates changes in pelvic volume related to injury and following treatment. ■ **Figure 6-7** illustrates prevention of external hip rotation. ■ **Figure 6-8** illustrates pelvic devices and associated PXR images.

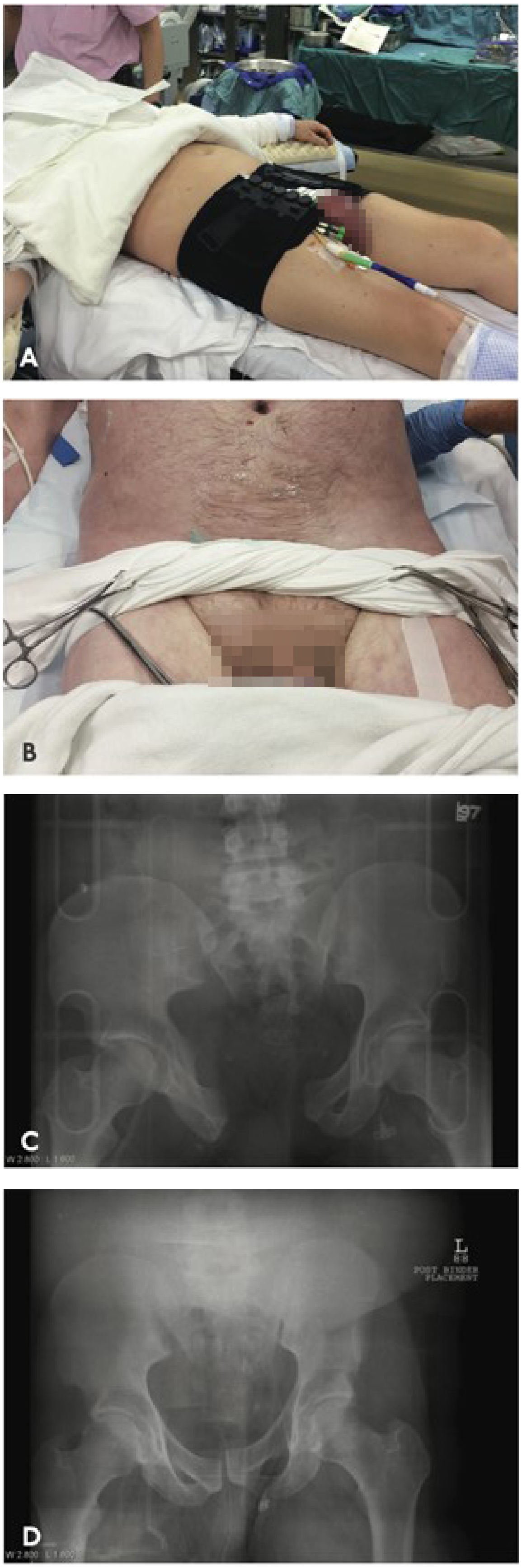
Internal bleeding due to long bone fractures may be lessened through fracture reduction, splinting, and/or traction. **For intra-abdominal bleeding identified on FAST and other uncontrolled hemorrhage, early surgical consultation is made to plan for definitive hemorrhage control.**

■ Figure 6-6: Changes in Pelvic Volume Related to Injury and Treatment. Red area represents potential pelvic volume. **A.** Uninjured pelvic volume. **B.** "Open book" pelvis. Increased pelvic volume associated with pubic rami fractures, disruption of the pubic symphysis, sacral fracture, and disruption of posterior ligaments. **C.** Placement of a pelvic compression sheet reduces potential pelvic volume. The sheet is centered on the greater trochanters (dotted line).





■ **Figure 6-7: Prevention of Hip External Rotation.** Binding of the lower extremities, with internal rotation of the hips if possible, helps to maintain pelvic compression.



■ **Figure 6-8. Temporary Pelvic Compression. A.** Commercial device. **B.** Sheet device. **C.** Radiograph prior to application of compression device. **D.** Radiograph following application of compression device.

RESTORATION OF VASCULAR VOLUME

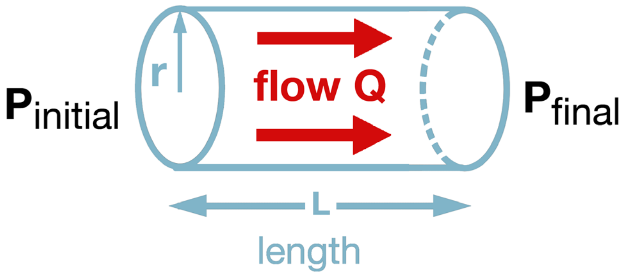
Fluid resuscitation is started prior to diagnostic procedures such as FAST and CT scan. IV access is established on patient arrival. Timely fluid administration is critical. Flow of fluid through a catheter is directly related to the radius to the 4th power and inversely related to eight times the length of the catheter. **■ Figure 6-9** illustrates a simplified equation for flow rate through a catheter. Therefore, **large-bore peripheral catheters (16 G and wider) are used** in shock resuscitation. **When peripheral IV access is challenging, an intraosseous (IO) device may be placed** while other options, such as central venous catheterization, are prepared. **■ Figure 6-10** illustrates IO insertion.

Red cells and other blood products, including whole blood, are the ideal resuscitative fluids. If these are unavailable, crystalloid may be administered. However, crystalloid resuscitation is minimized as much as is practical. Colloid and hypertonic solutions have no demonstrated benefit compared to isotonic crystalloids and are not commonly utilized for volume resuscitation of injured patients.

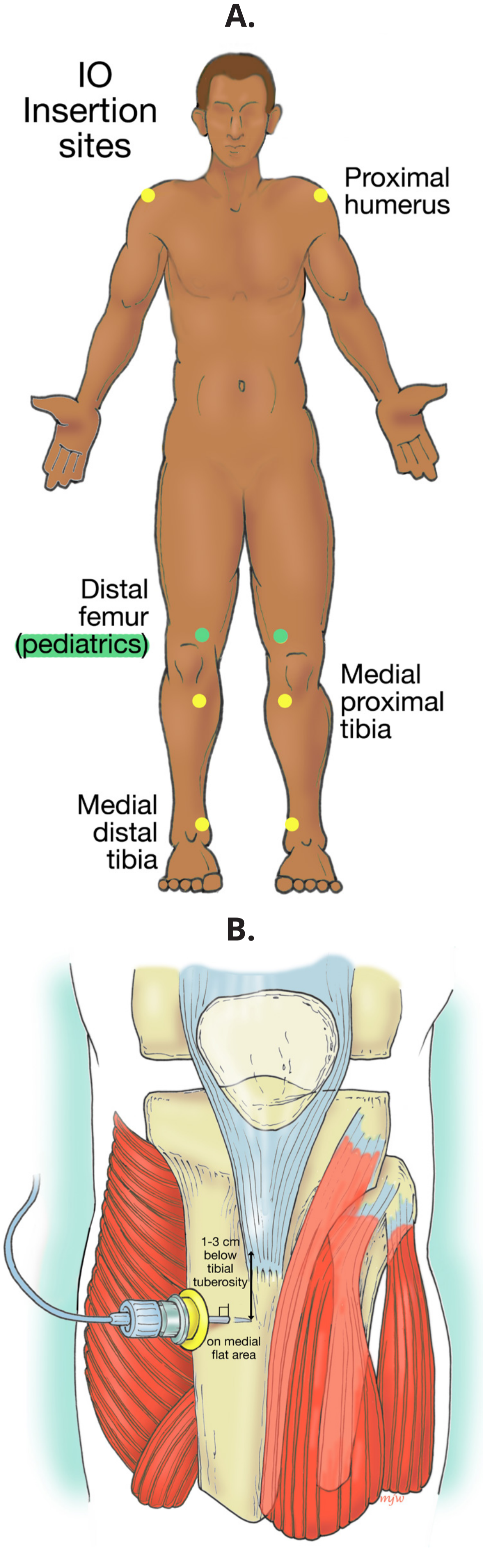
A goal blood product ratio of 1:1:1 (packed red blood cells to plasma products to platelets) is commonly practiced. Whole blood may be preferred. If blood products are not available in a timely fashion, resuscitation can be started with 250–500 mL crystalloids in adults and 10 mL/kg in children less than 20 kg. Fluids prewarmed to 39°C can minimize iatrogenic hypothermia. For actively hemorrhaging patients and those in extremis, group O packed red cells and AB plasma are rapidly transfused until type specific and cross-matched products are available. Products should be Rh negative in patients who may bear children and Rh positive in others.

■ Figure 6-9. Flow Rate of Vascular Access Catheters, Poiseuille's Law. Fluid may be infused faster through wide and short catheters. Flow is directly proportional to the radius to the 4th power and inversely proportional to 8x the length.

$$Q = \frac{(P_{final} - P_{initial})\pi r^{4}}{8\eta L}$$



■ Figure 6-10: Interosseous Access. A. Locations for IO access. Device should not be inserted distal to a fracture. Most common sites are at the humeral head and proximal tibia. **B.** A tibial IO is placed 1–3 cm distal to the tibial tuberosity on the medial tibia.



RESUSCITATION TARGETS IN HEMORRHAGIC SHOCK

Restoration of vascular volume to a “normal” blood pressure, either through blood product or crystalloid administration, may be detrimental in scenarios of uncontrolled hemorrhage. In such situations, a higher blood pressure may exacerbate bleeding. Permissive hypotension has been shown to improve mortality rates from hemorrhagic shock following truncal penetrating injuries. Normal mentation and palpable radial pulse of moderate volume are reasonable indicators of a balance between volume resuscitation and permissive hypotension if expeditious definitive hemostasis is planned.

Although definitive data in blunt trauma do not exist, permissive hypotensive resuscitation, similar to that for penetrating injury, to a systolic blood pressure of 90 mm Hg utilizing infusions of 100–200 mL of product (or fluid if no blood product is available) may be beneficial until definitive hemorrhage control is obtained. If a head injury, spinal cord injury, or a history of hypertension is present, a higher systolic pressure of 110 mm Hg may be more appropriate. **Permissive hypotension is not a replacement for available hemostatic intervention. It is not an acceptable modality to promote nonoperative management, during unsupervised transfers, or for management of blunt trauma with an identified source of bleeding in a center with adequate resources for hemorrhage control.**

ASSESSING RESPONSES TO RESUSCITATION

Measuring response to resuscitation depicts the severity of shock, directs subsequent management, and indicates urgency of definitive interventions or transfer. Observing the response to initial resuscitation can identify patients whose blood loss was greater than estimated and those with ongoing bleeding. Continuous monitoring is performed of vital signs and clinical signs of perfusion. **Supporting clinical assessment with objective measures for perfusion assessment is an invaluable component of resuscitation.**

Laboratory values such as lactate and base deficit, and urine output are valuable to monitor. Obtaining urine output of 0.5 mL/kg/hr in an adult and 1–2 mL/kg/hr in children would suggest adequate perfusion. However, change in these parameters takes time to occur. Therefore, they are not of great use in the acute resuscitation of trauma patients. The return of normal blood pressure, pulse pressure, and pulse rate are signs that perfusion is

■ **Table 6-4: Clinical Abnormalities in Shock and Signs of Improved Perfusion.** *Clinical values are evaluated as adjusted for age.

Clinical Abnormalities in Shock and Signs of Improved Perfusion			
System	**Shock**	**Improved perfusion**	**Limitations**
CNS	Agitation in early shock Lethargy in late shock	Improvement in sensorium	May be confounded by concomitant TBI, intoxication, and medications Can’t be assessed in intubated patient Interobserver variability
Skin	Cold, clammy Prolonged capillary refill time (<3 secs)	Improved temperature Improved capillary refill time	Subjective Confounded by external temperature
Renal	Pre-renal failure Oliguria anuria	Urine output adequate*	Evaluation takes hours No immediate index Chronic kidney disease Diuretics hyperglycemia
Hemodynamic	Tachycardia* Low-volume pulse by palpation Hypotension*	Trend towards normalization Palpable pulse volume improvement Normalization of BP	Noninvasive device not accurate Values may be falsely assuring Normalization of macrohemodynamics doesn’t signify normalization of perfusion at cellular level Medication effects, preinjury diseases

***Clinical values are evaluated as adjusted for age. BP, Blood pressure; TBI; Traumatic brain injury.**

returning to normal, but these observations do not ensure normal organ perfusion and tissue oxygenation. When the expertise exists, bedside eFAST assessment of inferior vena cava (IVC) size can be helpful in confirming adequacy/inadequacy of volume resuscitation.

Macrohemodynamic measurements (blood pressure, heart rate) are helpful in stratifying the response to initial resuscitation into three groups: responders, transient responders, and nonresponders.

Responders demonstrate normal hemodynamics following initial fluid administration. Signs of inadequate tissue perfusion have improved and are resolved. These patients typically have not lost a significant amount of blood and do not have active severe bleeding. Further blood product or fluid is not immediately indicated. However, when available, access to typed and crossmatched blood products is maintained. Further evaluation of injuries proceeds expeditiously.

Transient responders demonstrate improved hemodynamics following initial fluid administration. However, perfusion indices decline as the fluid rate is decreased, indicating either ongoing hemorrhage or inadequate resuscitation of previously lost blood. These patients have lost moderate to significant amounts of blood. Further transfusion (or crystalloid if blood is not available) is indicated. Surgical consultation is obtained when available, or transfer arrangements are initiated as operative or other invasive therapies may be employed to stop ongoing hemorrhage.

Failure to respond to volume administration indicates ongoing bleeding, inadequate resuscitation, or nonhemorrhagic shock. Reassessment and repeating the xABCDE survey may reveal a treatable source of shock. ■ **Table 6-5** illustrates etiologies for nonresponse to resuscitation. The medical history is reviewed for anticoagulant, antiplatelet, and glucocorticoid medications. External hemorrhage control and adequacy of tourniquets (if present) are evaluated, and pelvic compression or tube thoracostomy are considered.

■ **Table 6-5: Reasons for Nonresponse to Resuscitation.**

Reasons for Nonresponse to Resuscitation

REASON	ETIOLOGIES
Continuing Hemorrhage	Inadequately treated compressible hemorrhage *(unrecognized injury, inadequate wound packing, pelvic compression device, tourniquet)* Noncompressible bleeding *(intra-abdominal, pelvic arterial, penetrating junctional vessel injury)* Coagulopathy *(preinjury medications, unbalanced blood product administration, hyperfibrinolysis)*
Inadequate Resuscitation	Soft-tissue and intramuscular contusions and shearing injuries Fracture blood loss Concomitant burns Unrecognized blood loss prior to arrival
Non-Hemorrhagic Shock	Obstructive shock *(tension pneumothorax, tension hemothorax, cardiac tamponade)* Neurogenic shock Cardiogenic shock *(blunt cardiac injury, acute myocardial infarction)* Septic shock *(intra-abdominal sepsis, pneumonia, urinary sepsis)* Endocrine and metabolic *(diabetic ketoacidosis, adrenal insufficiency)*

In nonresponders, reassessment for nonhemorrhagic causes of shock (tension pneumothorax, cardiac tamponade, cardiac pump failure, neurogenic shock) is required. If a treatable cause is not diagnosed, urgent and definitive intervention (i.e., operation or angioembolization) to control exsanguinating internal hemorrhage is likely needed. Transfer arrangements are initiated if adequate expertise is not immediately available.

FACTORS CREATING VARIATION IN RESPONSE TO RESUSCITATION

The physiologic response to resuscitation may vary due to age, comorbidities, medications, athletic training, and pregnancy. The clinician considers these factors in evaluating the response to resuscitation and developing further management strategies. Although the wide range of "normal" vital signs and other factors makes the clinical diagnosis of shock challenging, the presence of metabolic acidosis is useful at any age to assess circulatory shock and response to resuscitation. ■ **Table 6-6** illustrates factors associated with variable response to resuscitation.

■ Table 6-6: Factors Associated with Variable Response to Resuscitation.

Patient Characteristic	Factors	Comments
Pregnant	Physiologic hypervolemia	Placental hypoperfusion may be present despite normal pulse and blood pressure
	Physiologic lower normal systolic pressure	Blood loss may be present without clinical signs of shock
	Vena cava compression by gravid uterus	Failure to displace uterus manually may explain poor response to resuscitation
Older Adult	Decreased sympathetic receptors Concomitant beta and calcium channel blockers Pacemakers	Tachycardiac compensation blunted absent; unable to increase cardiac output
	Diuretics with contracted blood volume	More severe shock and organ ischemia with relatively mild blood loss
	Atherosclerotic disease Preinjury reduced capacity for cardiac compensation	Increased risk of cardiac decompensation due to physiologic demand and risk of peri-injury myocardial infarction
Child	High sympathetic tone Efficient physiologic compensatory responses	Maintain vital signs until severe shock followed by rapid decompensation Respond to aggressive resuscitation even with profound shock Bradycardia more ominous sign than tachycardia
	Small absolute blood volume	Poor response to resuscitation due to failure to recognize proportion of blood lost
	Mobile and compliant tissues	Hypotension due to dilated stomach Potential for rapid development of tension pneumothorax
Athlete	Lower preinjury pulse rate	Less tachycardia per degree of shock
	Increased physiologic capacity for compensation	Risk of underestimating shock severity due to minimal signs

Children have age-specific normal vital signs. Due to lower circulating blood volume and efficient physiologic compensation to shock, the progression from minor to major shock may be rapid. Tachycardia and hypotension are usually late signs and are precursors to circulatory collapse. For additional information, please see *Chapter 11, Trauma in the Pediatric Patient.*

Injured older adults may have limited physiological capacity to compensate for blood loss, and ischemic organ damage can result after shorter durations of shock. The tachycardic response is usually absent with beta blocker therapy. The presence of antihypertensive medications may hamper physiologic vasoconstriction. Due to chronic changes, higher resuscitation blood pressure may be beneficial to ensure adequate organ perfusion in patients with preinjury hypertension. Pacemaker devices may impede the tachycardia compensation to shock. With reduced preload, cardiac output cannot respond to blood loss by increasing heart rate as expected. Heart rate may remain at the device's set rate regardless of volume status.

Athletes may have a low resting heart rate and a high capacity to increase cardiac output under stress. Thus, the degree of tachycardia and signs of hypoperfusion may be less pronounced. Astute clinicians recognize that a "normal" or slightly elevated heart rate may represent a significant compensatory mechanism, and the degree of shock may be more severe.

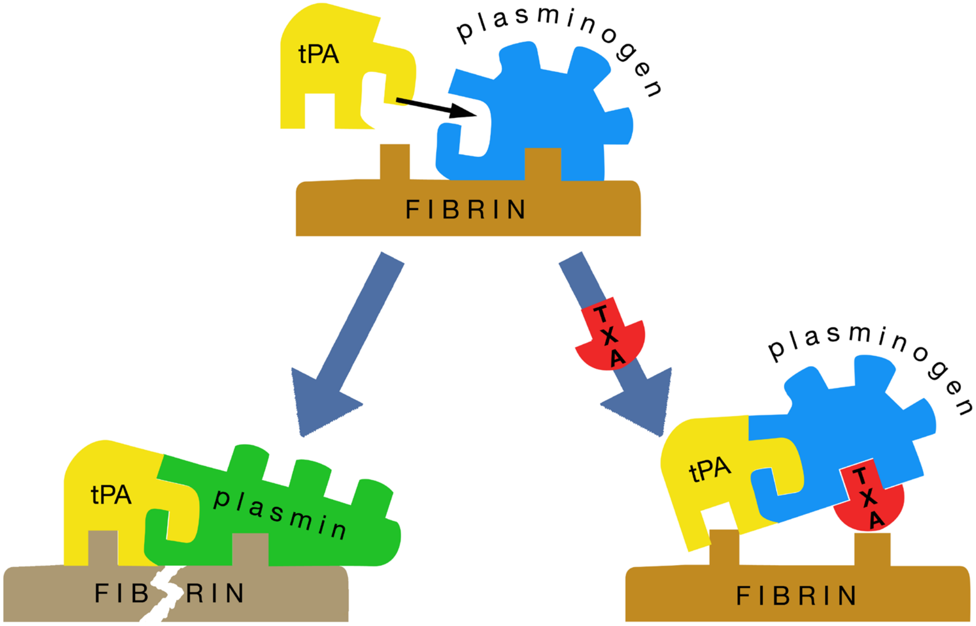
It can be challenging to determine a pregnant patient's normal preinjury vital signs due to physiologically expanded blood volume, tachycardia, and tachypnea. **In the third trimester, the uterus can compress the inferior vena cava in supine trauma patients, reducing cardiac preload. The response to resuscitation may be improved by shifting the uterus off the cava, either through placing the patient in a right side-up position or by manually displacing the uterus to the left.** Please see *Chapter 13, Trauma in the Pregnant Patient, Figure 13-8* for an illustration of this maneuver.

Intoxication with alcohol or other substances may limit the reliability of mental status evaluation in determining response to resuscitation. Altered mental status may be due to shock, cerebral injury, or substance effects.

TRANEXAMIC ACID IN HEMORRHAGE RESUSCITATION

Hyperfibrinolysis and coagulopathy are potential etiologies of continued bleeding and lack of response to resuscitation. **Tranexamic acid (TXA) may be administered in scenarios of major hemorrhagic shock** and is sometimes initiated in the prehospital setting. TXA is a synthetic, reversible competitive inhibitor to the lysine receptor on plasminogen. TXA prevents plasmin from binding to fibrin, thus reducing fibrinolysis and stabilizing a fibrin clot. ■ **Figure 6-11** illustrates the mechanism of action for TXA. When administered within 3 hours of injury, TXA has demonstrated a decrease in mortality in specific high-risk hypotensive bleeding populations. Local pharmacy protocols determine dosing. Clinically, both a 1 g TXA bolus within 3 hours from injury followed by second 1 g infusion over 8 hours, or a single dose of 2 g, have been safe and efficacious. TXA is not recommended to be administered beyond 3 hours from the time of injury unless hyperfibrinolysis is present.

■ **Figure 6-11: TXA Mechanism of Action.**
Pathologic hyperfibrinolysis may occur following trauma. This process will disrupt clot formation and contribute to uncontrolled hemorrhage. As illustrated on the left of the diagram, fibrinolysis is initiated when tissue plasminogen activator (tPA) binds to plasminogen, creating activated plasmin. Illustrated on the right of the diagram, tranexamic acid (TXA) binds to plasminogen, blocking its binding to fibrin and inhibiting fibrinolysis.



PREINJURY ANTICOAGULANT AND ANTIPLATELET AGENTS

Anticoagulant and antiplatelet medications are frequently prescribed for many cardiovascular, hematologic, and other disorders. As the number of older injured patients increases, clinicians are encountering patients receiving anticoagulant and/or antiplatelet agents on a more frequent basis. These drugs hinder clot formation through a variety of inhibitory mechanisms at the vitamin K, coagulation factor, and platelet aggregation phases. Biologic activity of anticlot drugs may complicate shock resuscitation and contribute to lack of response to treatment. Assays of PT, PTT, INR, and platelet count, along with viscoelastic testing, are routinely obtained when accessible. Anti-Xa activity tests exist but are relatively unavailable in emergent settings.

The decision to attempt reversal of the effects of anticlot agents is based on the clinical scenario. Unresponsive hemorrhagic shock, associated intracranial injury, plan for operative therapy, and other factors favor reversal. Prothrombin complexes, plasma, platelets, other blood products, and specific agents are administered per institutional availability, protocols, and surgeon recommendation. ■ **Table 6-7** illustrates treatment options for some common anticlotting medications. Anticoagulation and antiplatelet medications and recommendations for reversal of their effects change frequently. The clinician must remain informed through continued education. Reversal agents may produce severe thrombotic complications. Therefore, administration is limited to treatment of life-threatening, severe intracranial, or significant spinal hemorrhage.

VASOPRESSORS IN HEMORRHAGIC SHOCK

Vasopressor administration is not recommended as the primary management for hemorrhagic shock. These medications constrict precapillary arterioles and impair peripheral perfusion to improve blood pressure. **They may be used for temporary adjunctive management and to counteract hypotension from RSI medications.** Prolonged administration will worsen cellular perfusion.

NEUROGENIC SHOCK AND OTHER DISTRIBUTIVE ETIOLOGIES

The clinical scenario (mechanism and physical examination) may reveal signs consistent with neurogenic shock (hypotension, bradycardia, paralysis, numbness, and warm peripheral extremities). **As both neurogenic and hemorrhagic shock may occur simultaneously, the ATLS clinician ensures adequate control of hemorrhage while managing neurogenic shock** (*see Chapter 7, Disability: Neurological Assessment and Management*).

Resuscitation for neurogenic and other forms of distributive shock is initiated with volume resuscitation. In the absence of bleeding, isotonic crystalloid solutions are generally considered safe and beneficial. Hypotension is detrimental to neurologic recovery. **Therefore, blood pressure goals are higher (mean arterial pressure 85 mm Hg) during resuscitation when signs of isolated neurogenic shock are present.**

Vasopressors are added if volume fails to reach resuscitation goals. These medications restore peripheral vascular resistance. In neurogenic shock, norepinephrine is an option for injuries at all spinal levels. It has both α-1 and β-1 activity, which will improve peripheral vasoconstriction, heart rate, and contractility. Phenylephrine is another option for patients with spinal cord injury (SCI) below T6. However, as phenylephrine lacks β-1 activity, bradycardia may be exacerbated in scenarios with higher level spine injuries. Due to potential infusion site adverse effects, vasopressors are usually administered via central venous access. In emergencies, they can be infused through a peripheral IV until improved access is available.

OBSTRUCTIVE ETIOLOGIES

Tension pneumothorax is managed with emergent chest decompression as previously described (see *Chapter 5, Breathing and Ventilation Assessment and Management*). Operative intervention is indicated for management of cardiac tamponade with ultrasound-guided pericardiocentesis as a potential short-term temporizing maneuver. In near or active cardiac arrest, if adequately trained personnel and resources are available, a resuscitative left thoracotomy may be performed for release of tamponade, performance of direct cardiac massage, and control of bleeding.

CARDIOGENIC ETIOLOGIES

In the scenario of BCI, an abnormal echocardiogram (ECG) or rhythm on the monitor in the emergency department is associated with sudden critical arrhythmias. Patients with these findings may benefit from cardiac monitoring for 24–48 hours in an appropriate facility. Arrhythmias are treated in a fashion similar to nontrauma etiologies. Electrolytes, pH, oxygen, and carbon dioxide levels are maintained in normal ranges. Antiarrhythmic medications are administered as per non-BCI protocols.

Echocardiogram is useful to evaluate cardiac wall motion, output, and potential structural or valvular abnormalities. Data suggest that patients with a normal ECG in conjunction with normal levels of cardiac troponin can be safely discharged home, although this screening method will miss rare injuries with a delayed presentation like septal rupture.

ST segment elevation suggests either a contusion or myocardial infarction, potentially secondary to coronary artery injury. Cardiac angiography, angioplasty, or surgery may be beneficial. Similarly, if a complete heart block is present, temporary or permanent pacemaker insertion may be indicated. Transfer for these complex cardiothoracic surgery and cardiology evaluations may be performed if the resources are available at other institutions.

TRAUMATIC CARDIAC ARREST

Following severe injury, loss of palpable pulses and blood pressure may occur either prior to or shortly after emergency area arrival. The mortality in this clinical situation is extremely high.

The etiology and management of traumatic cardiac arrest (TCA) differ from management of nontraumatic cardiac arrest. Due to depleted intravascular volume, CPR is ineffective. Restoration of intravascular volume is paramount and takes priority over chest compressions and Advanced Cardiac Life Support (ACLS) measures.

■ Table 6-7: Recommended Options for Reversal of Effects of Anticlotting Medications.

Recommended Options for Reversal of Effects of Anticlotting Medications

Anticlotting Agent	Treatment Options	Comments
Antiplatelet agents e.g., aspirin clopidogrel / Plavix® ticagrelor / Brilinta® prasugrel / Effient® dipyridamole/ Persantine® aspirin + dipyridamole / Aggrenox® adciximab / Reopro® eptifibatide / Integrilin® tirofiban / Aggrastat®	***Determine if minor or major bleeding** **Minor:** Desmopressin acetate (DDAVP) 0.3 mg kg single dose **Major:** Platelet transfusion for life-threatening hemorrhage or planned neurosurgical intervention Routine platelet transfusion without benefit, potential harm DDAVP 0.4 mg kg TXA may be beneficial Eaminocaproic acid (EACA) 4 g loading dose followed by 1 g/h maximum of 4 hours	Routine platelet transfusion demonstrated worse outcomes in one study Desmopressin acetate (DDAVP) has theoretical application but data on efficacy are lacking Residual antiplatelet medication may inhibit transfused platelets Eaminocaproic acid (EACA) may increase DVT risk
Vitamin K antagonists e.g., warfarin / Coumadin®	Vitamin K 5–10 mg IV Plus: Four-factor PCC^# or FFP start 10-15 ml kg	Normalize INR Monitor for volume overload in elderly patients and cardiac injury patients
Oral direct thrombin inhibitor e.g., dabigatran / Pradaxa®	Idarucizumab (Praxbind) 5g IV or Four-factor PCC^&	Consider activated charcoal if last-known dose within 2 hours
IV direct thrombin inhibitors e.g., bivalirudin Angiomax® argatroban	FFP 15 ml kg (may repeat)	Idarucizumab (Praxbind) is not effective and not FDA approved Metabolized in 2–6 hrs Dialysis potential to clear bivalirudin.
Factor Xa inhibitors rivaroxaban / Xarelto® and apixaban / Eliquis®	Andexanet alpha (Andexxa®) or Four-factor prothrombin complex concentrate^&	Dosage adjusted by timing of last dose of anticoagulant+ Low-dose protocol (400 mg IV bolus then 480 mg infusion over 2 hours) or high-dose protocol (800 mg bolus, 960 mg / 2 hrs) Consider activated charcoal if last-known dose within 2 hours
Factor Xa Inhibitor edoxaban / Lixiana®, Savaysa®	Off-label andexanet alpha (Andexxa®) or Four-factor PCC^&	High-dose protocol (800 mg bolus, 960 mg / 2 hrs)
Factor Xa Inhibitor fondaparinux / Arixtra®	**Off label** andexanet alpha (Andexxa®) or aPCC / FEIBA® 20 u / kg single dose if aPCC not available rVIIa / Novoseven® 90 mcg kg single dose	Dose of Andexanet alpha not established
Heparin continuous infusion	Protamine sulfate	1 mg 100 units unfractionated heparin in past 2 hours, maximum 50 mg Monitor PTT
Low-molecular-weight heparin e.g., enoxaparin / Lovenox® dalteparin / Fragmin® tinzaparin / Innohep® nadroparin / Fraxiparine®	Protamine sulfate	If dose within 8 hours: 1 mg per mg LMWH (maximum 50 mg protamine) Dose 8–12 hours: 0.5 mg per mg LMWH No dosing if >12 hours

- **TXA, Tranexamic acid; DVT, Deep venous thrombosis; PCC, Prothrombin complex concentrate; FFP, Fresh frozen plasma; INR, International Normalized Ratio; aPCC, Activated prothrombin complex concentrate; rVIIa, recombinant factor Viia; PTT, Partial thromboplastin time.**
- ***Minor bleeding: Clinically uncontrolled hemorrhage, less than 5 g/dl decrease in hemoglobin or less than 15% decrease in hematocrit. Major bleeding: Clinically significant intracranial hemorrhage, more than 5 g/dl decrease in hemoglobin concentration, or more than 15% decrease in hematocrit with hemodynamic compromise or compression of a vital structure.**
- **^e.g., Kcentra®, Beriplex®, Confidex®, Balfaxar®, Octaplex®.**
- **#Dosing either 1,000–5,000 units fixed dose or staged by INR (INR 2 - <4 = 25 u/kg; 4-6 = 35 u/kg; >6 50 u/kg). Higher fixed doses sometimes recommended for intracranial hemorrhage.**
- **+Use low-dose protocol if last dose of rivaroxaban was ≤10 mg, last dose of apixaban was ≤5 mg or unknown dose of rivaroxaban or apixaban was ≥8 hours prior. Use high dose if >10 mg dose of rivaroxaban, >5 mg dose of apixaban, or unknown dose <8 hours prior or unknown time; or if an unknown dose of rivaroxaban or apixaban was within 8 hours prior.**
- **& Either fixed dose 2,000–5,000 units or 40-50 u/kg, maximum dose 5,000 units.**

The major causes of TCA include hypovolemia/hemorrhagic shock (circulation), hypoxemia (airway/breathing), tension pneumothorax (breathing/circulation) and cardiac tamponade (circulation). These are treated expeditiously. The clinician ensures an airway is maintained, oxygen is supplied, external bleeding is controlled, fluids are rapidly administered, and both chest cavities are decompressed. If there is return of an organized cardiac rhythm and a measurable blood pressure, resuscitation is continued.

According to local policy, resources, and surgical availability, a resuscitative thoracotomy may be indicated if there is no return of spontaneous circulation (ROSC). Several algorithms are available for management of TCA in penetrating injury for centers with surgical expertise in emergency resuscitative thoracotomy.

If there is no improvement and there are no signs of life, functional survival is unlikely, and resuscitation may terminate. ■ **Table 6-8** lists commonly accepted signs of life. Resuscitation is futile if CPR has been performed for longer than 10 minutes following blunt trauma, longer than 15 minutes following penetrating trauma, or if ultrasound demonstrates the absence of cardiac tamponade and no cardiac motion when the only sign of life is electrical activity. The decision to cease resuscitative efforts is challenging for all team members. Availability of structured professional support and debriefing are beneficial and recommended.

■ Table 6-8: Signs of Life for Assessment During Traumatic Cardiac Arrest.

SIGN
Pupillary response
Spontaneous ventilation
Palpable pulse
Measurable blood pressure
Extremity movement
Electrical cardiac activity

TRANSFER CONSIDERATIONS

During the Circulation stage of xABCDE assessment, conditions may be identified for which the current institution does not have sufficient resources. This may include operative or catheter-based interventions for hemorrhage control, transfusion, specialized care units (intensive care, cardiac monitoring, burns, pediatrics, obstetrics), or multidisciplinary specialist care (orthopaedic, plastic/reconstructive, neurosurgery, spine surgery). Once an indication for transfer is identified, arrangements are initiated. **Resuscitation and management of shock is continued until and during transfer with clear plans for continued volume resuscitation (blood products and crystalloids as available) and contingencies for identified bleeding wounds, airway maintenance, and breathing abnormalities.**

CHAPTER SUMMARY

Shock is the clinical manifestation of circulatory compromise, with varying clinical and physiological signs depending on the severity as well as individual patient factors. Hemorrhagic shock, the most common cause in trauma, requires rapid recognition and control of ongoing bleeding. Management focuses on identifying the cause of shock to enable tailored interventions.

KEY LEARNING POINTS

- **Identify and evaluate shock in trauma patients, including assessing blood loss and intravascular volume status.**
- **Hemorrhage is the most common cause of shock in the trauma patient.**
- **Address circulation abnormalities during the primary survey and initiate appropriate resuscitation strategies.**
- **Reassess and adapt the resuscitation approach based on the patient's response to treatment.**
- **Recognize limitations of resources and consider patient transfer if necessary for optimal management.**

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7

Disability: Neurological Assessment and Management

OBJECTIVES

After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Describe the relationship of intracranial anatomy and intracranial pressure physiology to common brain injuries
2. Determine appropriate patients and techniques for spinal motion restriction
3. Describe a neurological and trauma-focused medical history
4. Identify the components of a focused brain neurological examination in a trauma scenario
5. Explain as assessment of spinal cord function with physical examination and relationship to spine anatomy
6. Identify options, indications, and interpretation of brain and spinal imaging
7. Describe the primary survey, goals of resuscitation, and prevention of secondary traumatic brain and spinal cord injury
8. Recognize and manage neurogenic shock and neuroworsening
9. Determine appropriate disposition of brain and spinal cord trauma patients

07

Disability: Neurological Assessment and Management

CHAPTER STATEMENT

Traumatic brain and spinal cord injuries share similar pathophysiological mechanisms and vulnerability to secondary insults, where prompt detection and intervention are crucial for improving neurological outcomes.

INTRODUCTION

The Disability, "D" portion of xABCDE involves assessment of the two portions of the central nervous system, the brain and the spinal cord. Traumatic brain injury (TBI) and traumatic spinal cord injury (SCI) are leading causes of death and disability worldwide. Care is complex and expensive. Falls and road injuries are the leading causes. According to the Global Burden of Disease Study, in 2016 there were 27 million new cases of TBI and nearly 1 million new cases of SCI worldwide. In the US alone, TBI is associated with an estimated 4.8 million emergency department visits and hospitalizations per year and with at least one-quarter of all trauma-related deaths. While more than 80% of cases are mild, a considerable proportion of TBI survivors incur temporary or permanent disability. The cost to the global economy is equivalent to $400 billion USD. The global incidence of SCI ranges from 15 to 40 cases per million, with data from the US indicating 55 new cases per million annually, excluding prehospital deaths. While statistics that enumerate spinal column fractures (SCFs) are not readily available, they are estimated to occur approximately eight times more frequently than cord injuries.

For both brain and spinal injuries, older patients with unintentional falls are a growing percentage of patients seen in emergency departments and trauma centers. According to the Centers for Disease Control and Prevention, in 2014, more than 837,000 cases of TBI occurred among children in the US. The initial management of the multisystem trauma patient can improve survival and long-term functional outcomes of TBI and SCI patients by preventing secondary insults and worsening of the primary injury. Time is crucial. Implementing early appropriate resuscitation while performing the Initial Assessment and Primary Survey is essential, especially in rural and limited-resource areas, where TBI-related mortality is higher. The central tenets of managing TBI and SCI are prevention and treatment of hypoxia and hypotension by following ATLS® principles of stopping external bleeding, airway management, breathing management, and circulation management.

ANATOMY, PHYSIOLOGY, AND PATHOLOGY OF TBI AND SCI

TRAUMATIC BRAIN INJURY

TBI is characterized by anatomical and functional changes following an external force. The primary brain injury happens during impact with tissue damage which may result in an acute change in the level of consciousness. Secondary brain injury is an additional insult that may occur after the initial injury due to intracranial or systemic complications such as hypotension and hypoxemia. TBI is described by the anatomic location of injury. **■ Figure 7-1** illustrates the anatomy of various brain injuries.

PATHOLOGIC ANATOMY OF COMMON BRAIN INJURIES

Extradural Hematoma

Extradural hematoma (EDH) is a collection of blood between the skull's inner table and the dura mater's parietal layer. As a result, EDHs are usually limited in extent by the cranial sutures and usually have a biconvex shape. **More than 75% of EDHs are caused by a torn middle meningeal artery** and are associated with skull fractures. A vertex EDH is caused by venous bleeding from the sagittal sinus and often crosses the midline. Brain tissue is usually minimally injured in patients with isolated EDH. Related brain injury is invariably secondary to shift and pressure. **If prompt operation is performed, most patients recover without neurological deficits.**

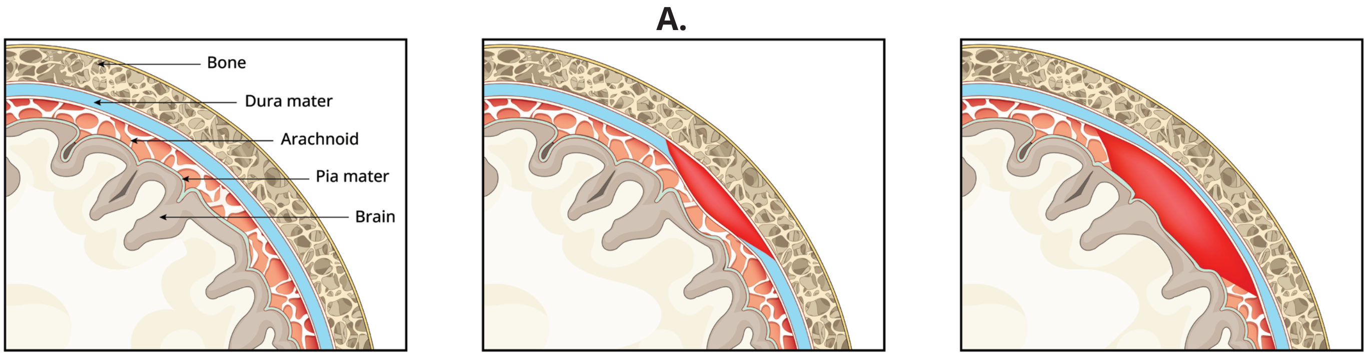
Subdural Hematoma

Subdural hematoma (SDH) is a collection of blood in the subdural space. SDHs occur following a rapid deacceleration of the head. The brain continues to move, leading to stretching and rupturing of bridging cortical veins. The arachnoid is also injured, resulting in a mixture of cerebrospinal fluid (CSF) and blood in the subdural space. Subdural hematomas occur between the dura and arachnoid, resulting in a crescent shape on CT scan. Subdural hematomas are not limited by cranial sutures but by dural reflections such as the falx cerebri, tentorium, and falx cerebelli. Acute subdural hematomas, especially in younger patients, are frequently associated with brain contusions. Most SDHs are unilateral in adults. However, in infants, the majority are bilateral. **The presence of a SDH in an infant may be due to physical abuse.** Isolated interhemispheric or parafalcine SDHs are common in infant maltreatment injury.

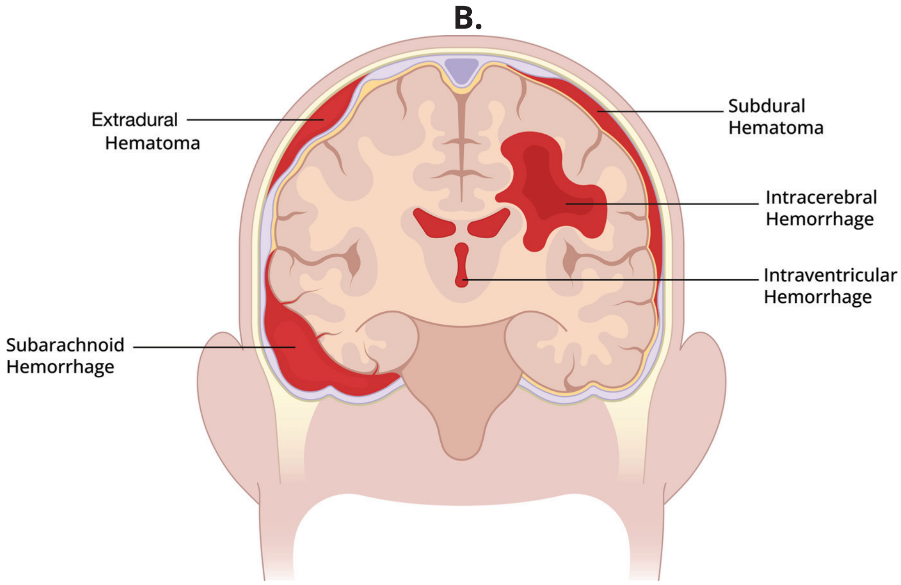
Traumatic Subarachnoid Hemorrhage

Traumatic subarachnoid hemorrhage (tSAH) is the presence of blood in the subarachnoid spaces, such as cerebral sulci, fissures, or cisterns. The exact mechanism remains unclear. Proposed mechanisms include shearing of small veins or arteries, arterial dissection, or direct extravasation from cerebral contusions.

■ **Figure 7-1: Anatomy of Brain Injuries. A.** Normal anatomy, extradural hematoma, and subdural hematoma. **B.** Different types of intracranial hematomas and hemorrhages.



Normal **Extradural hemotoma** **Subdural hemotoma**



Cerebral Contusion

A cerebral contusion is an injury to the brain parenchyma. The brain may be directly damaged by application of an external force or by a sudden deceleration causing the brain to strike the skull. Back-and-forth movement of the brain within the skull may produce both coup (side of force) or contrecoup (opposite side of force) injuries. Most contusions occur in the frontal and temporal lobes, where the brain moves against the rough surface of the anterior cranial fossa floor. Contusions may progress in size, bleeding, and physiologic effect in the first 24 hours, with a reported incidence of progression between 16% and 75%.

Axonal Injury

Traumatic axonal injury is caused by rotational acceleration or deceleration forces, resulting in shearing of the neurons. The white and grey matter have different specific gravities, resulting in movement relative to each other as the brain comes to rest after sudden deceleration. This leads to the shearing of axons in the white matter, swelling, and disconnection. **Diffuse axonal injury is a multifocal injury.**

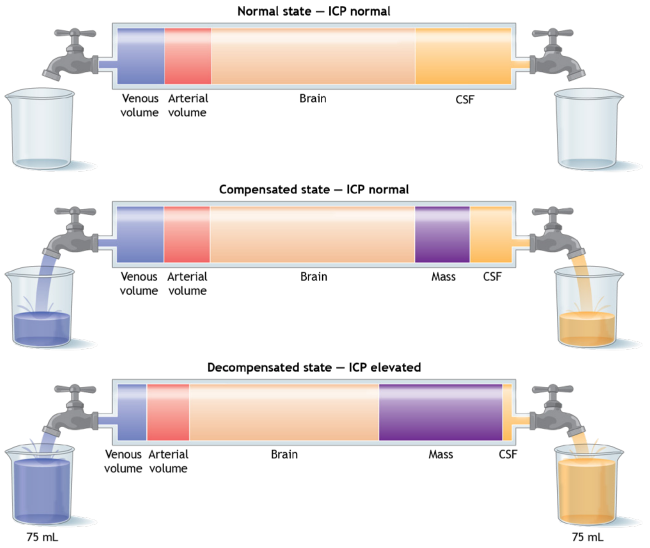
PATHOPHYSIOLOGY OF BRAIN INJURIES

Intracranial Pressure and Herniation Syndromes

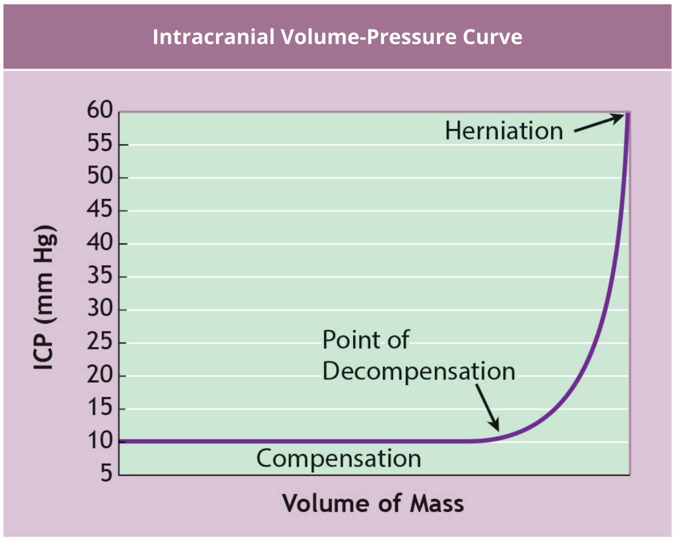
Intracranial pressure (ICP) is measured inside the skull and is exerted by the intracranial contents (the brain, CSF, and cerebral blood volumes). Normal ICP for adults is 7–15 mm Hg supine and can be as low as –10 mm Hg while upright. ICP may rise when the volume of one of the three components increases. **The Monroe-Kellie doctrine states that due to the fixed volume of the skull, the sum of brain, CSF, intracranial blood volume, and any pathological process must remain constant to maintain a normal ICP. Therefore, an increase in the volume of one component is compensated by a decrease of one of the others.**

After injury, intracranial volume may be increased due to cerebral edema or mass lesions such as extradural, subdural, or intracerebral hematomas. Compensatory displacement of CSF and cerebral blood volume can maintain a low ICP. However, with increased pathologic volume, compensatory mechanisms are eventually exhausted and ICP rises, resulting in cerebral ischemia. ■ **Figure 7-2** illustrates the Monroe-Kellie Doctrine. ■ **Figure 7-3** illustrates the relationship between intracranial volume and ICP.

■ **Figure 7-2: The Monroe-Kellie Doctrine Regarding Intracranial Compensation for Expanding Mass.** The total volume of the intracranial contents remains constant. If the addition of a mass such as a hematoma compresses an equal volume of CSF and venous blood, ICP remains normal. However, when this compensatory mechanism is exhausted, ICP increases exponentially for even a small additional increase in hematoma volume. (Adapted with permission from Narayan RK. Head Injury. In: Grossman RG, Hamilton WJ eds., *Principles of Neurosurgery*. New York, NY: Raven Press, 1991.).

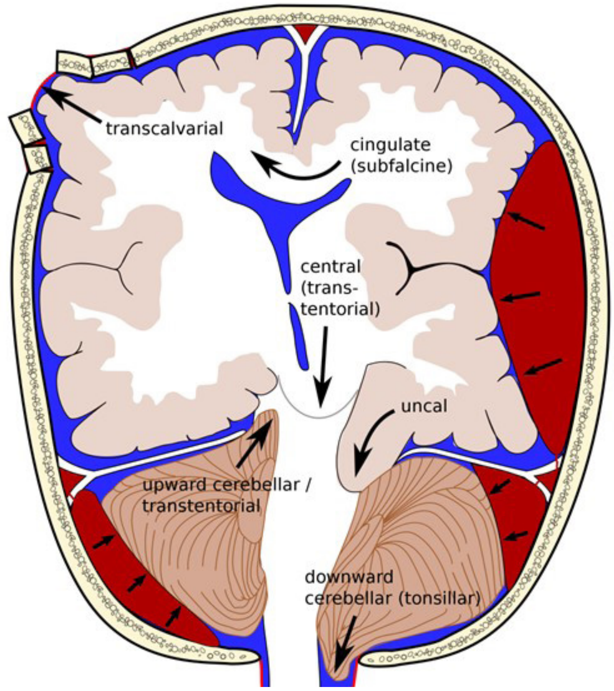

Normal state – ICP normal
Venous volume
Arterial volume
Brain
CSF
Compensated state – ICP normal
Venous volume
Arterial volume
Brain
Mass
CSF
Decompensated state – ICP elevated
Venous volume
Arterial volume
Brain
Mass
CSF
75 mL
75 mL

■ **Figure 7-3: Intracranial Volume – Pressure Curve.** The intracranial contents initially can compensate for a new intracranial mass, such as a subdural or epidural hematoma. Once the volume of this mass reaches a critical threshold, a rapid increase in ICP often occurs, which can lead to reduction or cessation of cerebral blood flow.



The intracranial space is subdivided into compartments by dural septa. A pressure differential between adjacent compartments may result in herniation of brain tissue from one compartment to another. This is the final event of unrelieved intracranial hypertension and produces complete collapse of cerebral vasculature and brain death. ■ **Figure 7-4** illustrates several types of cerebral herniation.

■ **Figure 7-4: Types of Cerebral Herniation.** Uncal herniation is the most common herniation syndrome. Subfalcine herniation occurs when the brain herniates across the midline. Central herniation compresses the midbrain. Ascending transtentorial herniation occurs when a cerebellar mass pushes the brain upward through the cerebellar tentorium, compressing the midbrain. Tonsillar herniation occurs when the cerebellar tonsils push against the foramen magnum, compressing the medulla and upper cervical cord. Tonsillar herniation is clinically manifested by apnea and a rapid rise in the blood pressure.


transcalvarial
cingulate (subfalcine)
central (trans-tentorial)
uncal
upward cerebellar / transtentorial
downward cerebellar (tonsillar)

Uncal Herniation

Descending unilateral transtentorial (uncal) herniation is the most common type of herniation syndrome. It is caused by the temporal lobe pushing downward over the tentorial edge. ***Uncal herniation*** **is manifested by progressively impaired consciousness, a dilated pupil on the side of injury (due to third cranial nerve palsy), and progressive weakness with abnormal posturing.**

Subfalcine and Central Herniation

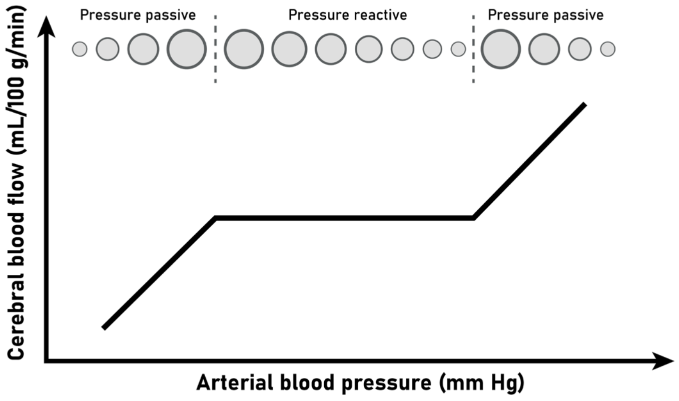
Subfalcine herniation occurs when the brain herniates under the falx cerebri into the opposite side, usually due to a unilateral frontal of parietal mass such as a EDH or SDH. Central herniation occurs when a cerebral hemisphere is displaced downward, compressing and displacing the midbrain. These herniation syndromes are characterized by impaired consciousness, abnormal posturing, and abnormal respiration. They are often the fatal sequela of TBI.

Cerebral Blood Flow

Cerebral blood flow (CBF) is expressed as blood volume per 100 grams of tissue per minute. Normally, CBF represents 15% of resting total cardiac output. **Cerebral perfusion pressure (CPP) is the difference between mean arterial pressure (MAP) and ICP.** Normal average CPP is 60–80 mm Hg. The ability of the brain to maintain constant CBF across a wide range of CPP or MAP is called cerebral autoregulation.

Cerebral autoregulation is achieved by alteration of cerebral vascular resistance. As MAP or CPP falls, blood vessels dilate. When MAP or CPP increases, vessels constrict. Thus, CBF remains constant. When physiologic autoregulation is disrupted by injury, blood flow varies with CPP changes, resulting in hypo- or hyperperfusion, rendering the injured brain more susceptible to ischemia, expansion of hemorrhage, and increased ICP. ■ **Figure 7-5** illustrates CBF autoregulation.

■ **Figure 7-5: Cerebral Blood Flow Autoregulation Curve.** Cerebral blood flow is normally constant across a range of blood pressure.

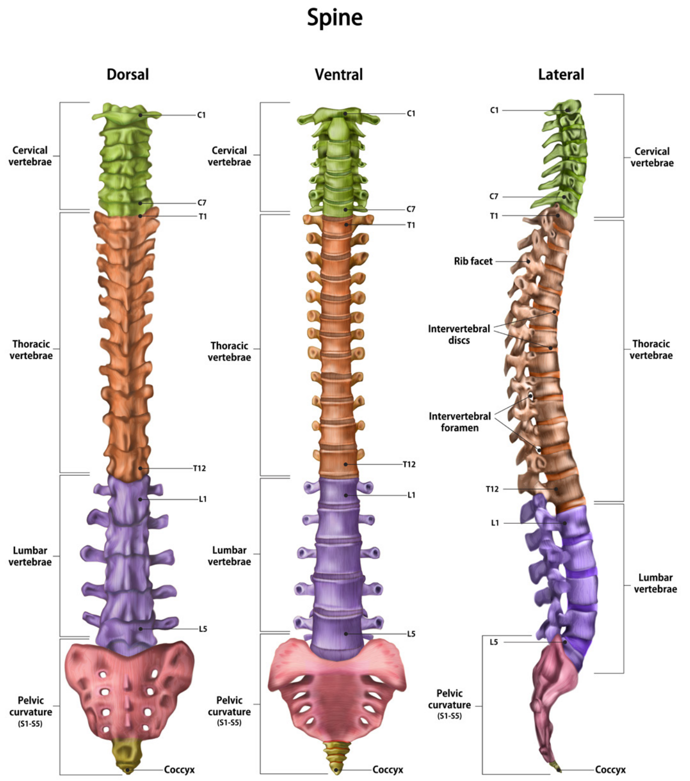


SPINAL CORD INJURY

ANATOMY

The spinal axis comprises seven cervical (C), 12 thoracic (T), and five lumbar (L) articulating vertebrae, followed by nine fused vertebrae—five sacral (S) and four coccygeal. ■ **Figure 7-6** illustrates spinal column anatomy. The first cervical vertebra, C1, is ring shaped without a defined anatomic body and articulates with the skull at the occipital condyles superiorly. ■ **Figure 7-7** and ■ **Figure 7-8** illustrate anatomy of the cervical vertebrae. The second cervical vertebra, C2, has a body with a superior extension (the odontoid process, or dens) that articulates with the anterior arch of C1. This articulation is stabilized by a transverse ligament that spans the posterior aspect of the dens and attaches to the lateral masses of C1. The third cervical to thoracolumbar vertebrae comprise a body, bilateral pedicles, lamina, and articular facets.

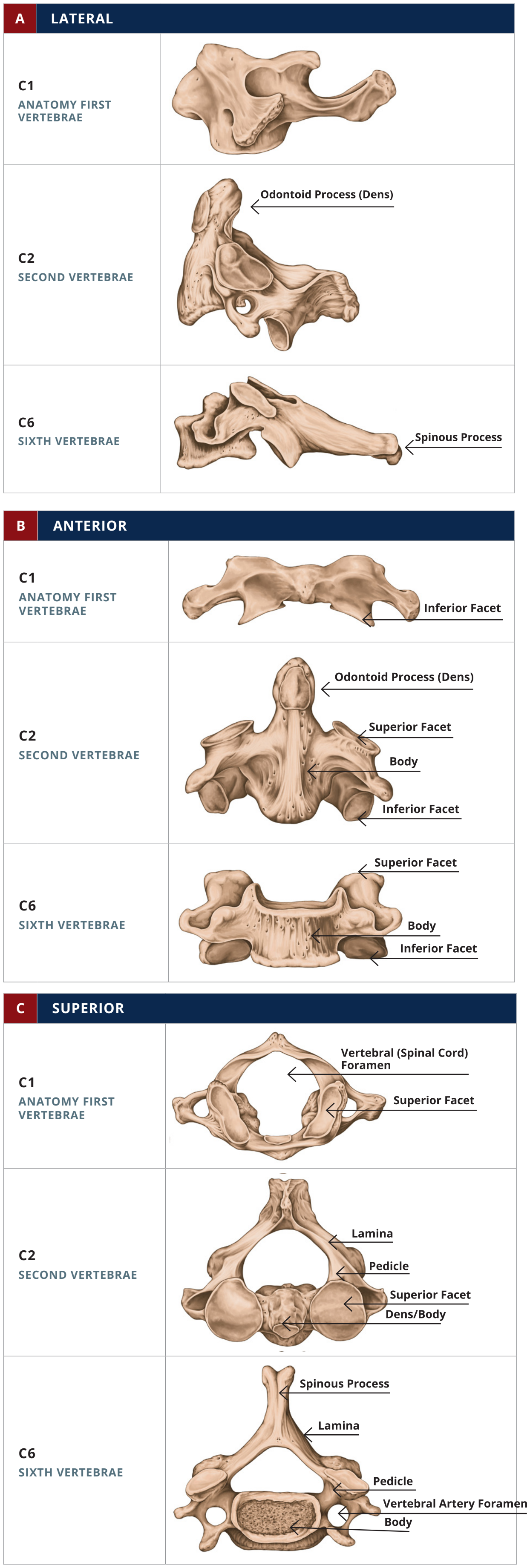
■ **Figure 7-6: Spinal Column Anatomy.**



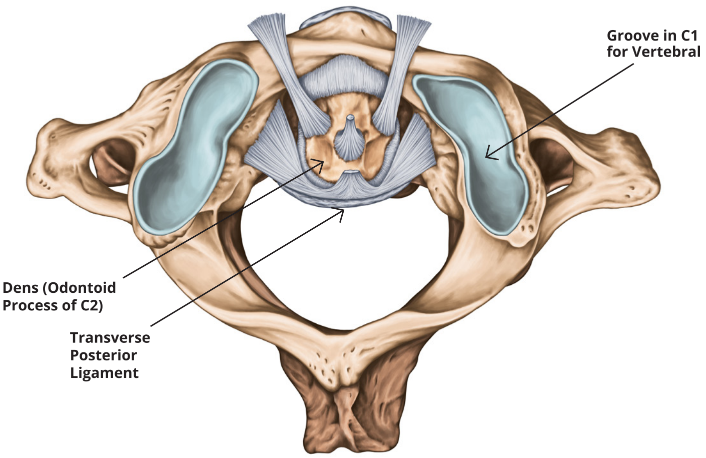
Several ligaments provide structural stability. ■ **Figure 7-9** illustrates spinal ligaments. The ligaments secure adjacent vertebrae, stabilizing the spinal column by limiting excessive movement. Vertebral bodies and intervertebral discs bear compressive loads, while ligaments bear rotational, distractive, and shear forces. The cervical nuchal ligament continues caudally on the thoracic and lumbar spine as the supraspinous ligament.

The spinal cord and meninges are located inside the vertebral canal. In adults, the spinal canal extends from the foramen magnum to the level of the first and second lumbar vertebrae. The grey matter of the spinal cord is located centrally and divided into dorsal sensory and ventral motor zones. White matter is located peripherally and comprises sensory dorsal and mixed anterior and lateral columns. ■ **Figure 7-10** illustrates spinal cord motor and sensory tracts.

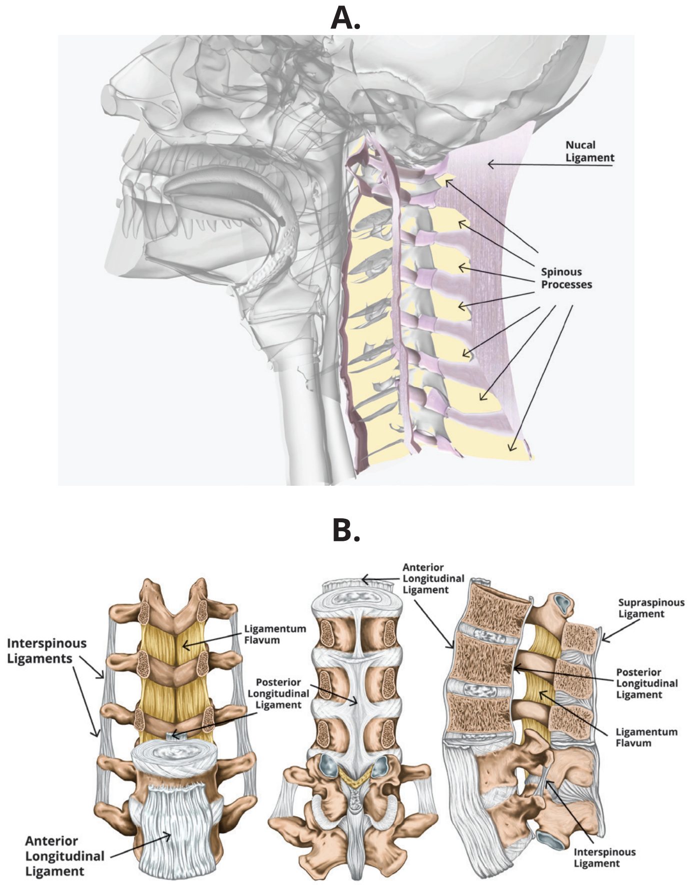
■ **Figure 7-7: Anatomy First (C1), Second (C2), and Sixth (C6) Vertebrae.** **A.** Lateral **B.** Anterior **C.** Superior.


A
LATERAL
C1
ANATOMY FIRST VERTEBRAE
C2
SECOND VERTEBRAE
Odontoid Process (Dens)
C6
SIXTH VERTEBRAE
Spinous Process
B
ANTERIOR
C1
ANATOMY FIRST VERTEBRAE
Inferior Facet
C2
SECOND VERTEBRAE
Odontoid Process (Dens)
Superior Facet
Body
Inferior Facet
C6
SIXTH VERTEBRAE
Superior Facet
Body
Inferior Facet
C
SUPERIOR
C1
ANATOMY FIRST VERTEBRAE
Vertebral (Spinal Cord) Foramen
Superior Facet
C2
SECOND VERTEBRAE
Lamina
Pedicle
Superior Facet
Dens/Body
C6
SIXTH VERTEBRAE
Spinous Process
Lamina
Pedicle
Vertebral Artery Foramen
Body

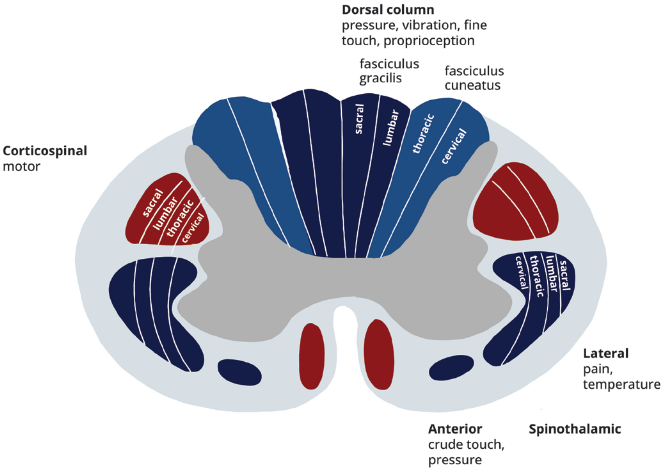
■ **Figure 7-8: First Cervical Vertebra with Dens.** The transverse ligament stabilizes the odontoid process.


Groove in C1 for Vertebral
Dens (Odontoid Process of C2)
Transverse Posterior Ligament

■ **Figure 7-9: Spinal Ligaments.** **A.** The nuchal ligament is attached along the posterior aspect of the cervical spine from the occiput to the spinous process of C7. **B.** Lumbar spinal ligaments. These ligaments are present throughout the spine.


A.
Nucal Ligament
Spinous Processes
B.
Anterior Longitudinal Ligament
Supraspinous Ligament
Interspinous Ligaments
Ligamentum Flavum
Posterior Longitudinal Ligament
Posterior Longitudinal Ligament
Ligamentum Flavum
Anterior Longitudinal Ligament
Interspinous Ligament

■ Figure 7-10: Spinal Motor and Sensory Tracts.



PATHOPHYSIOLOGY

Half of patients with traumatic SCI present with isolated cord injury, while one-quarter present with concomitant injuries to the brain, chest, and extremities. SCI in a multisystem trauma scenario presents additional challenges due to the potential deleterious impact of other injuries leading to secondary SCI. Blunt or penetrating trauma to the spinal column may cause SCI by several mechanisms. **■ Table 7-1** lists some mechanisms of SCI.

Injuries occur in the areas of highest spinal mobility. Therefore, cervical injuries account for more than 50% of cases. The C3–C7 region is more prone to injury, accounting for 65% of fractures and 75% of dislocations. Cervical spine injuries carry higher rates of mortality and morbidity when compared to thoracic or lumbar injuries. The most common types of SCI are listed in **■ Table 7-2**.

■ Table 7-1: Types and Mechanisms of SCI.

Types and Mechanisms of SCI

Mechanism	Description
Direct Injury	Penetrating or blunt injury may produce any degree of transection through laceration or distraction/displacement of a spinal column bony element into the canal.
Compression	Mass effect of a spinal canal hematoma such as an epidural hematoma. In older adults with cervical spondylosis or osteoarthritis, the spinal cord may be tethered or compressed between the anterior vertebral ridge and calcified ligaments during sudden cervical hyperextension.
Contusions	Caused by dislocation, retropulsion of fracture fragments, or subluxation.
Vascular Injury	Fractures through the transverse foramina or dislocation of the lower cervical vertebrae cause stretching, dissection or direct injury, leading to thrombosis of vertebral arteries, resulting in ischemia.

■ Table 7-2: Relative Frequencies of Types of SCI.

Relative Frequencies of Types of SCI

Common types of SCI	Percentage
Incomplete tetraplegia	31%
Complete paraplegia	25%
Complete tetraplegia	20%
Incomplete paraplegia	19%

SCI = Spinal cord injury

Neurogenic Shock

Neurogenic shock is a distributive shock with hypotension and bradycardia caused by the loss of vasomotor tone and cardiac sympathetic innervation when cord injury occurs above the T6 level. Interruption of the sympathetic chain results in unopposed vagal tone. Low blood pressure can exacerbate primary cord injury due to decreased spinal cord perfusion. Higher (more cranial) and more complete SCI tends to result in more severe and more refractory shock. The cardiovascular effects can develop within hours to days of injury and may last 1 to 3 weeks. In contrast to hemorrhagic shock, neurogenic shock typically leads to hypotension and bradycardia with warm and dry skin. The ATLS mnemonic (xABCDE) is followed during assessment and management of potential neurogenic shock.

Spinal Shock

The term "spinal shock" is a misnomer and has no relation to hemodynamic instability. Spinal shock is characterized by a transient loss of muscle tone and areflexia distal to the anatomical lesion that occurs immediately following an SCI. The magnitude of spinal shock is related to the severity and rapidity of the injury. Spinal shock can persist for days up to a week and can be prolonged by sepsis or critical illness polyneuropathy. As reflexes distal to the level of injury recover first, resolution of spinal shock may be indicated by return of a plantar or bulbocavernosus reflex.

SPINAL MOTION RESTRICTION

Excessive movement of the spine with spinal column injury can exacerbate existing injury or create injury to the spinal cord. The term *"spinal motion restriction"* (SMR) is preferred to "spinal immobilization," as current techniques are unable to provide complete immobilization. **■ Table 7-3** lists some indications for SMR. SMR may be achieved with a cervical collar, backboard (used for brief periods and not long transfers), scoop stretcher, vacuum splint, neutral alignment on a cot or stretcher, or any similar devices. SMR is applied to the whole spine due to the high risk of noncontiguous injuries. A correctly sized cervical collar is a component of SMR. The spine is restricted to align the head, neck, and torso. SMR is not performed in the sitting position. Transfer from one surface to another is performed with care. A long spine board, scoop stretcher, or vacuum mattress

■ Table 7-3: Indications for Spinal Motion Restriction Following High Energy Blunt Mechanism.

Indications for Spinal Motion Restriction Following High Energy Blunt Mechanism	
Adult	**Pediatric**
• Acutely altered level of consciousness (e.g., GCS <15, potential substance intoxication) • Midline neck or back pain and/or tenderness • Focal neurologic signs and/or tenderness • Anatomic deformity of the spine • Distracting circumstances or injury that impairs a reliable examination (e.g., long bone fracture, degloving or crush injury, large burns, emotional distress, communication barrier)	• Complaint of neck pain • Torticollis • Neurologic deficit • Altered mental status (GCS < 15, potential substance intoxication, agitation, apnea, somnolence) • Motor vehicle crash, high-impact diving injury, substantial torso injury

may be utilized for transfer to minimize axial spinal movements. **Routine SMR and cervical collar application are not performed for penetrating mechanisms.** SMR and a cervical collar may be indicated if clinical exam indicates potential spinal trauma.

Cervical collars are applied to the pediatric population per Pediatric Emergency Care Applied Research Network (PECARN) recommendations. The incidence of contiguous and noncontinuous multilevel spine injury is very low in children. To minimize pressure ulcer risk and discomfort in children, vacuum mattresses are favored and time on backboards is limited. Younger children have a higher head-to-torso size ratio. Additional padding may be placed to avoid excessive neck flexion and obtain neutral spine alignment.

DISABILITY ASSESSMENT DURING PRIMARY SURVEY

Evaluation of both brain and spinal cord function is performed during the disability portion of the Primary Survey. If an airway disorder is to be managed by intubation, a rapid and very focused determination of pupil responses, gross extremity motor and sensory function, and Glasgow Coma Scale (GCS) score prior to administration of RSI medications is beneficial.

A history is ascertained from prehospital providers or observers, or from the patient (if TBI is mild or absent). History regarding usage of anticoagulants and antiplatelet drugs is critical in relevant clinical contexts. The estimated elapsed time from injury, GCS at the scene, pupil size and reactions, and any changes in neurological status are obtained from prehospital providers and documented. **History of loss of consciousness with a return to alertness (lucid interval), followed by a lapse into unconsciousness, is correlated with the presence and expansion of an EDH.**

GCS assessment is performed by first observing spontaneous activities prior to stimulus. Verbal stimuli are provided next, while observing eye opening, verbal responses, and upper-extremity motor responses. When there is no response to verbal stimuli, another stimulus (e.g., fingertip pressure, supraorbital pressure, trapezius pinch) is applied, and responses are recorded. The severity of brain injury is defined by the post-resuscitation total GCS in the absence of sedation and neuromuscular blockage. **■ Table 7-4** reviews GCS scoring. **■ Table 7-5** lists the classification of TBI by total GCS score.

■ Table 7-4: Glasgow Coma Scale and Scores. The Glasgow Coma Scale is composed of three components: eye opening, verbal response, and motor response. The Glasgow Coma Score (GCS) is determined by the best response obtained following testing each component. The total GCS is determined by adding each individual score, noting NT (non-testable) when applicable. Of the three components, the motor component is most correlated with long term outcomes following traumatic brain injury.

Glasgow Coma Scale and Scores		
Component	**Result**	**Score**
Eye Opening (E)	Spontaneous	4
	To sound	3
	To pressure	2
	None	1
	Non-testable	NT
Verbal Response (V)	Oriented	5
	Confused conversation	4
	Words	3
	Sounds	2
	None	1
	Non-testable	NT
Motor Response (M)	Obeys commands	6
	Localizing	5
	Normal flexion (withdrawal)	4
	Abdnormal flexion	3
	Extension	2
	None	1
	Non-testable	NT

■ **Table 7-5: Classes of TBI.** TBI can be divided into three groups by GCS score.

Classification of TBI by GCS Score	
Classification	**GCS score**
Severe TBI	≤ 8
Moderate TBI	9–12
Mild TBI	13–15

TBI, Traumatic brain injury;
GCS, Glasgow Coma Scale.

The resting size of the pupils and their reaction to a strong light is assessed after gently opening the eyelids. Midsized (4–5 mm) bilateral nonreactive pupils may indicate midbrain injury. As the brain herniates, the ipsilateral pupil dilates. Asymmetrical motor response is assessed and recorded to identify lateralizing signs indicative of unilateral intracranial mass lesion or SCI. Bilateral fixed and dilated pupils are associated with a poor prognosis.

During the primary survey, the clinician observes for asymmetric motor or sensory findings such as lack of movement in extremities on one side or in specific limbs. Patients with a complete high (proximal) SCI may respond only by facial grimacing or neck movements.

DISABILITY ASSESSMENT DURING SECONDARY SURVEY

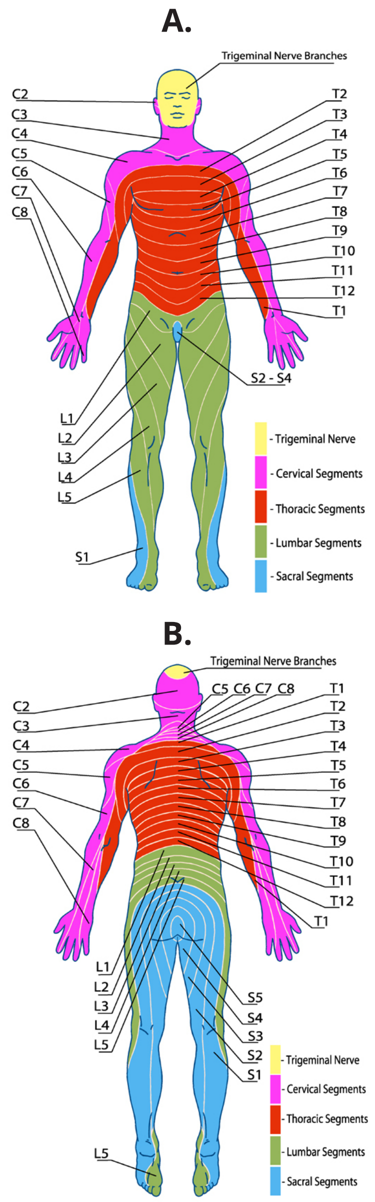
Once the primary survey is completed, the secondary survey is performed with a complete head-to-toe assessment. Brain and spinal cord function are assessed and recorded. Most spinal column injuries are detected and evaluated during the secondary survey. **When mechanism or other factors are consistent with potential spinal injury, SMR is maintained throughout the secondary survey.** Both blunt and penetrating trauma may cause a SCI.

External head and neck examination is performed to identify a skull deformity, an open fracture of the skull, brain herniation, scalp lacerations, CSF leakage from the nose or ears, and **signs of basal skull fracture (e.g., "racoon eyes," "battle sign" bruising over the mastoid).** The location of penetrating and other wounds is ascertained and documented. The entire spinal column and paravertebral musculature is examined and palpated for areas of deformity or focal tenderness. Vertebral fractures or subluxations may be associated with a palpable "step-off". **Loss of bowel or bladder control and priapism are signs of potential SCI.** While maintaining SMR, gentle palpation of the posterior neck is performed to assess for areas of deformity or focal tenderness.

SCI can be categorized as incomplete or complete and as paraplegia (thoracic or lumbar injury) or quadriplegia/tetraplegia (cervical injury). Motor or sensory function below (caudal to) the injury level indicates an incomplete injury. **Signs of an incomplete injury include sensation (including position sense) or voluntary movement in the lower extremities, sacral sensation and/or motor sparing, voluntary anal sphincter contraction, and voluntary toe flexion.** Sacral reflexes, such as the bulbocavernosus reflex or anal wink, do not qualify as sacral sparing. **Early, accurate documentation of sensation and strength is essential to assess neurological improvement or deterioration on subsequent examinations.**

Sensory evaluation evaluates for a deficit within dermatome segments. A dermatome is the area of skin innervated within a particular segmental nerve root. The sensory level is the lowest (most caudal) dermatome with normal sensory function and can often differ on the two sides of the body. ■ **Figure 7-11** illustrates spinal dermatomes. ■ **Table 7-6** lists locations of several spinal dermatomes.

■ **Figure 7-11: Spinal Cord Dermatomes. A**. Anterior. **B.** Posterior.


A.
Trigeminal Nerve Branches
C2
C3
C4
C5
C6
C7
C8
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
T1
S2 - S4
L1
L2
L3
L4
L5
S1
- Trigeminal Nerve
- Cervical Segments
- Thoracic Segments
- Lumbar Segments
- Sacral Segments
B.
Trigeminal Nerve Branches
C5 C6 C7 C8
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
T1
C2
C3
C4
C5
C6
C7
C8
L1
L2
L3
L4
L5
S5
S4
S3
S2
S1
L5
- Trigeminal Nerve
- Cervical Segments
- Thoracic Segments
- Lumbar Segments
- Sacral Segments

■ **Table 7-6: Sensory Function Related to Spinal Cord Level (Dermatomes).**

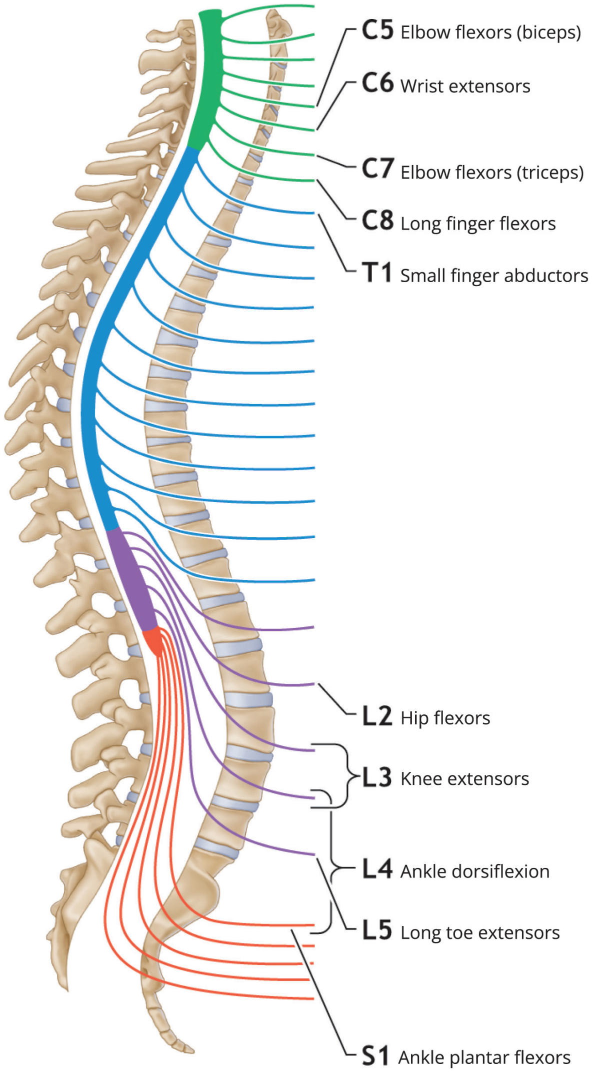
Sensory Function Related to Spinal Cord Level (Dermatomes)

Dermatome	Innervation
C5	Over the deltoid
C6	Thumb
C7	Middle finger
C8	Little finger
T4	Nipple line
T8	Xyphoid
T10	Umbilicus
T12	Symphysis pubis
L4	Medial aspect of the calf
L5	Web space between the first and second toes
S1	Lateral border of the foot
S3	Ischial tuberosity
S4 and S5	Perianal region

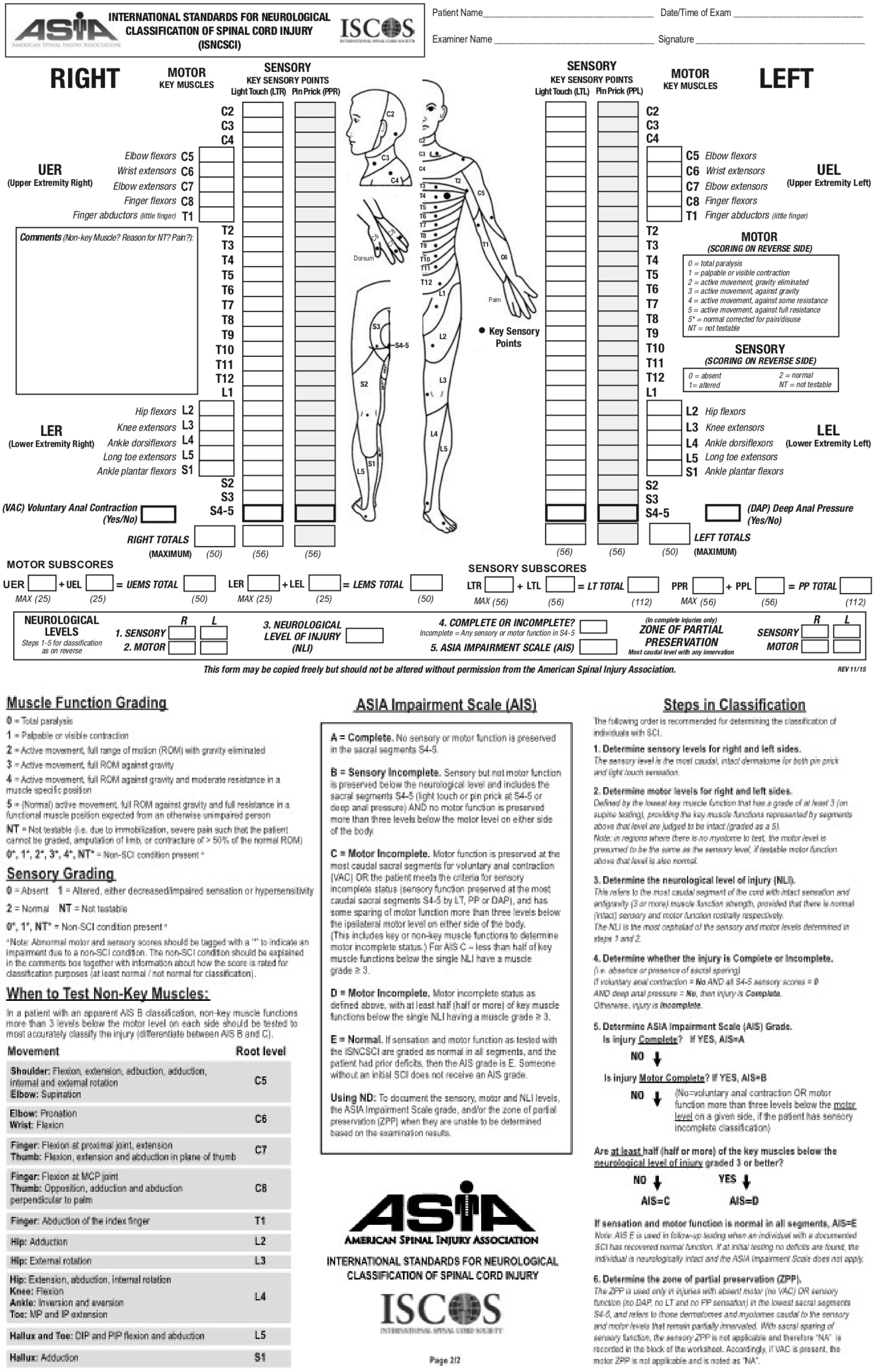
Motor examination evaluates for absent or diminished motor function due to either lateralizing TBI or SCI. Key extremity muscle groups are examined systematically and bilaterally. ■ **Figure 7-12** illustrates spinal myotomes. Strength is graded from zero (paralysis) to five (normal strength). A rectal exam and an evaluation for spinal reflexes are performed. The presence of rectal tone and sensation may be the only manifestations of neurologic function caudal to the anatomic level of injury. These findings reclassify the injury from "complete" to "incomplete," which has significant prognostic value and may alter management. The presence or absence of a bulbocavernosus reflex is tested. Priapism may be seen, most commonly in a complete cervical SCI.

The International Standards for Neurological Classification of Spinal Cord Injury worksheet, also known as the American Spinal Injury Association (ASIA) score, is an accepted standard for assigning the level and grade of injury. ■ **Figure 7-13** illustrates a spinal cord injury worksheet. The ASIA score follows a standardized physical examination consisting of myotome, dermatome, and rectal tone examinations. Functional outcomes of SCI are variable and depend on the severity of neurological injury at presentation. The level of injury is also related to outcomes. Incomplete SCI tends to carry a more favorable prognosis.

■ **Figure 7-12: Spinal Cord Myotomes.**


C5 Elbow flexors (biceps)
C6 Wrist extensors
C7 Elbow flexors (triceps)
C8 Long finger flexors
T1 Small finger abductors
L2 Hip flexors
L3 Knee extensors
L4 Ankle dorsiflexion
L5 Long toe extensors
S1 Ankle plantar flexors

■ Figure 7-13: International Standards for Neurological Classification of Spinal Cord Injury Worksheet.


C2
C3
C4
C5
C6
C7
C8
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
S1
S2
S3
S4-5
Dorsum
Palm

INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY (ISNCSCI)

Patient Name________________ Date/Time of Exam ________________

Examiner Name ________________ Signature ________________

RIGHT MOTOR KEY MUSCLES		SENSORY KEY SENSORY POINTS Light Touch (LTR)	Pin Prick (PPR)	SENSORY KEY SENSORY POINTS Light Touch (LTL)	Pin Prick (PPL)		LEFT MOTOR KEY MUSCLES
	C2					C2	
	C3					C3	
	C4					C4	
UER (Upper Extremity Right) Elbow flexors	C5					C5	Elbow flexors UEL (Upper Extremity Left)
Wrist extensors	C6					C6	Wrist extensors
Elbow extensors	C7					C7	Elbow extensors
Finger flexors	C8					C8	Finger flexors
Finger abductors (little finger)	T1					T1	Finger abductors (little finger)
	T2					T2	
	T3					T3	
	T4					T4	
	T5					T5	
	T6					T6	
	T7					T7	
	T8					T8	
	T9					T9	
	T10					T10	
	T11					T11	
	T12					T12	
	L1					L1	
LER (Lower Extremity Right) Hip flexors	L2					L2	Hip flexors LEL (Lower Extremity Left)
Knee extensors	L3					L3	Knee extensors
Ankle dorsiflexors	L4					L4	Ankle dorsiflexors
Long toe extensors	L5					L5	Long toe extensors
Ankle plantar flexors	S1					S1	Ankle plantar flexors
	S2					S2	
	S3					S3	
(VAC) Voluntary Anal Contraction (Yes/No)	S4-5					S4-5	(DAP) Deep Anal Pressure (Yes/No)
RIGHT TOTALS (MAXIMUM) (50)		(56)	(56)	(56)	(56)		(50) LEFT TOTALS (MAXIMUM)

Comments (Non-key Muscle? Reason for NT? Pain?):

● Key Sensory Points

MOTOR
(SCORING ON REVERSE SIDE)
0 = total paralysis
1 = palpable or visible contraction
2 = active movement, gravity eliminated
3 = active movement, against gravity
4 = active movement, against some resistance
5 = active movement, against full resistance
5* = normal corrected for pain/disuse
NT = not testable

SENSORY
(SCORING ON REVERSE SIDE)
0 = absent
1= altered
2 = normal
NT = not testable

MOTOR SUBSCORES

UER ☐ + UEL ☐ = UEMS TOTAL ☐ MAX (25) (25) (50)

LER ☐ + LEL ☐ = LEMS TOTAL ☐ MAX (25) (25) (50)

SENSORY SUBSCORES

LTR ☐ + LTL ☐ = LT TOTAL ☐ MAX (56) (56) (112)

PPR ☐ + PPL ☐ = PP TOTAL ☐ MAX (56) (56) (112)

NEUROLOGICAL LEVELS
Steps 1-5 for classification as on reverse

	R	L
1. SENSORY	☐	☐
2. MOTOR	☐	☐

3. NEUROLOGICAL LEVEL OF INJURY (NLI) ☐

4. COMPLETE OR INCOMPLETE? ☐
Incomplete = Any sensory or motor function in S4-5

5. ASIA IMPAIRMENT SCALE (AIS) ☐

(In complete injuries only)
ZONE OF PARTIAL PRESERVATION
Most caudal level with any innervation

	R	L
SENSORY	☐	☐
MOTOR	☐	☐

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REV 11/15

Muscle Function Grading

0 = Total paralysis

1 = Palpable or visible contraction

2 = Active movement, full range of motion (ROM) with gravity eliminated

3 = Active movement, full ROM against gravity

4 = Active movement, full ROM against gravity and moderate resistance in a muscle specific position

5 = (Normal) active movement, full ROM against gravity and full resistance in a functional muscle position expected from an otherwise unimpaired person

NT = Not testable (i.e. due to immobilization, severe pain such that the patient cannot be graded, amputation of limb, or contracture of > 50% of the normal ROM)

0*, 1*, 2*, 3*, 4*, NT* = Non-SCI condition present *

Sensory Grading

0 = Absent **1** = Altered, either decreased/impaired sensation or hypersensitivity

2 = Normal **NT** = Not testable

0*, 1*, NT* = Non-SCI condition present *

Note: Abnormal motor and sensory scores should be tagged with a "" to indicate an impairment due to a non-SCI condition. The non-SCI condition should be explained in the comments box together with information about how the score is rated for classification purposes (at least normal / not normal for classification).

When to Test Non-Key Muscles:

In a patient with an apparent AIS B classification, non-key muscle functions more than 3 levels below the motor level on each side should be tested to most accurately classify the injury (differentiate between AIS B and C).

Movement	Root level
Shoulder: Flexion, extension, adbuction, adduction, internal and external rotation **Elbow:** Supination	C5
Elbow: Pronation **Wrist:** Flexion	C6
Finger: Flexion at proximal joint, extension **Thumb:** Flexion, extension and abduction in plane of thumb	C7
Finger: Flexion at MCP joint **Thumb:** Opposition, adduction and abduction perpendicular to palm	C8
Finger: Abduction of the index finger	T1
Hip: Adduction	L2
Hip: External rotation	L3
Hip: Extension, abduction, internal rotation **Knee:** Flexion **Ankle:** Inversion and eversion **Toe:** MP and IP extension	L4
Hallux and Toe: DIP and PIP flexion and abduction	L5
Hallux: Adduction	S1

ASIA Impairment Scale (AIS)

A = Complete. No sensory or motor function is preserved in the sacral segments S4-5.

B = Sensory Incomplete. Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-5 (light touch or pin prick at S4-5 or deep anal pressure) AND no motor function is preserved more than three levels below the motor level on either side of the body.

C = Motor Incomplete. Motor function is preserved at the most caudal sacral segments for voluntary anal contraction (VAC) OR the patient meets the criteria for sensory incomplete status (sensory function preserved at the most caudal sacral segments S4-5 by LT, PP or DAP), and has some sparing of motor function more than three levels below the ipsilateral motor level on either side of the body. (This includes key or non-key muscle functions to determine motor incomplete status.) For AIS C – less than half of key muscle functions below the single NLI have a muscle grade ≥ 3.

D = Motor Incomplete. Motor incomplete status as defined above, with at least half (half or more) of key muscle functions below the single NLI having a muscle grade ≥ 3.

E = Normal. If sensation and motor function as tested with the ISNCSCI are graded as normal in all segments, and the patient had prior deficits, then the AIS grade is E. Someone without an initial SCI does not receive an AIS grade.

Using ND: To document the sensory, motor and NLI levels, the ASIA Impairment Scale grade, and/or the zone of partial preservation (ZPP) when they are unable to be determined based on the examination results.

AMERICAN SPINAL INJURY ASSOCIATION

INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

ISCOS
INTERNATIONAL SPINAL CORD SOCIETY

Page 2/2

Steps in Classification

The following order is recommended for determining the classification of individuals with SCI.

1. Determine sensory levels for right and left sides.
The sensory level is the most caudal, intact dermatome for both pin prick and light touch sensation.

2. Determine motor levels for right and left sides.
Defined by the lowest key muscle function that has a grade of at least 3 (on supine testing), providing the key muscle functions represented by segments above that level are judged to be intact (graded as a 5).
Note: in regions where there is no myotome to test, the motor level is presumed to be the same as the sensory level, if testable motor function above that level is also normal.

3. Determine the neurological level of injury (NLI).
This refers to the most caudal segment of the cord with intact sensation and antigravity (3 or more) muscle function strength, provided that there is normal (intact) sensory and motor function rostrally respectively.
The NLI is the most cephalad of the sensory and motor levels determined in steps 1 and 2.

4. Determine whether the injury is Complete or Incomplete.
(i.e. absence or presence of sacral sparing)
*If voluntary anal contraction = **No** AND all S4-5 sensory scores = 0*
*AND deep anal pressure = **No**, then injury is **Complete**.*
*Otherwise, injury is **Incomplete**.*

5. Determine ASIA Impairment Scale (AIS) Grade.
Is injury Complete? If YES, AIS=A
NO ↓
Is injury Motor Complete? If YES, AIS=B
NO ↓ (No=voluntary anal contraction OR motor function more than three levels below the motor level on a given side, if the patient has sensory incomplete classification)

Are at least half (half or more) of the key muscles below the neurological level of injury graded 3 or better?
NO ↓ AIS=C
YES ↓ AIS=D

If sensation and motor function is normal in all segments, AIS=E
Note: AIS E is used in follow-up testing when an individual with a documented SCI has recovered normal function. If at initial testing no deficits are found, the individual is neurologically intact and the ASIA Impairment Scale does not apply.

6. Determine the zone of partial preservation (ZPP).
The ZPP is used only in injuries with absent motor (no VAC) OR sensory function (no DAP, no LT and no PP sensation) in the lowest sacral segments S4-5, and refers to those dermatomes and myotomes caudal to the sensory and motor levels that remain partially innervated. With sacral sparing of sensory function, the sensory ZPP is not applicable and therefore "NA" is recorded in the block of the worksheet. Accordingly, if VAC is present, the motor ZPP is not applicable and is noted as "NA".

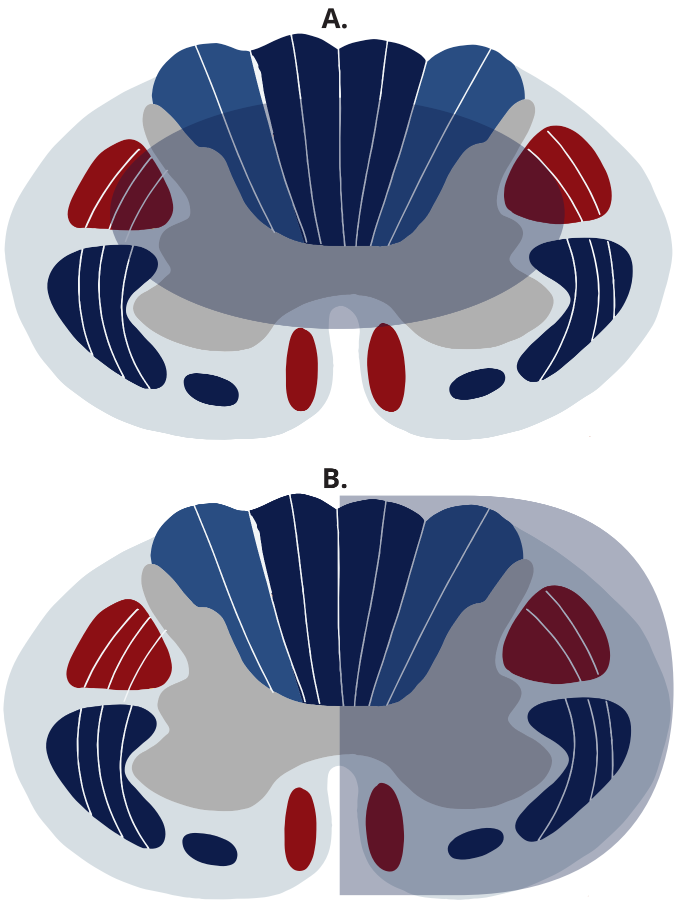
SCI SYNDROMES

SCI syndromes occur with incomplete SCI and manifest in specific patterns of neurological deficits. ■ **Figure 7-14** illustrates several SCI syndromes. Other spinal cord syndromes, such as anterior and posterior cord syndromes, are rare following trauma and are usually due to vascular pathology.

CENTRAL CORD SYNDROME

Central cord syndrome accounts for 15%–25% of all SCIs. It is associated with cervical hyperextension in patients with preinjury spinal stenosis. Thus, it is more common in older than younger patients. Motor deficits are disproportionately present in the upper extremities compared to the lower extremities. Varying degrees of sensory impairment and bladder/bowel dysfunction occur.

■ **Figure 7-14: Spinal Cord Syndromes.** Shaded areas represent regions of injury. **A.** Central cord syndrome. Examination demonstrates disproportionate upper-limb weakness, bladder dysfunction, and variable sensory dysfunction. **B.** Brown – Séquard syndrome. Examination demonstrates ipsilateral dorsal column sensory loss, contralateral spinothalamic sensory loss, and ipsilateral motor loss.



BROWN-SÉQUARD SYNDROME

Brown-Séquard syndrome is an uncommon, incomplete SCI, accounting for 4% of SCI. It is usually presents following a gunshot, or knife wound that creates injury to one side of the spinal cord. Clinical features of Brown-Séquard syndrome are as follows:

- Ipsilateral loss of vibration, proprioception, and fine touch (dorsal column sensations)
- Contralateral loss of pain, temperature, and crude touch (spinothalamic tract sensations)
- Ipsilateral loss of motor function (corticospinal tract injury)

PERIPHERAL NERVE INJURY

Blunt and penetrating mechanisms have the potential to cause damage to the peripheral nervous system. Peripheral nerve injury (PNI) can lead to permanent disability and decreased quality of life. A thorough neurological examination diagnoses the injury. PNI is associated with arterial, venous, and joint dislocation injuries. If a joint is dislocated and associated with PNI, emergent reduction is performed. A consultation with a peripheral nerve surgeon (when available) is performed once a nerve injury is identified.

ADJUNCTS

IMAGING ADJUNCTS TO ASSESSMENT

Evaluation of brain and spine injuries through radiological assessment is performed for a comprehensive trauma evaluation. However, during the primary survey, xABCDE are completed with adequate cardiac and respiratory status obtained before transport for imaging. A significantly altered mental status (GCS ≤ 12) or high-risk mechanisms of injury, such as explosions, high-speed motor vehicle collisions, and falls from great heights, are generally assessed with whole-body multidetector CT scanning when available. When transfer for higher level of care is indicated, transport is not delayed to obtain images.

TRAUMATIC BRAIN INJURY

The preferred imaging modality for TBI is a noncontrast CT scan of the brain. Advantages include accessibility, rapidity, cost-effectiveness, and high sensitivity for detecting acute intracranial conditions such as hemorrhage, edema, volume shifts, and skull fractures. The 2023 American College of Emergency Physicians (ACEP) clinical policy reviewed the Canadian CT Head Rule, New Orleans Criteria, and NEXUS Head CT decision tools. The summary indications to consider a head CT are listed in ■ **Table 7-7**. **A GCS ≤ 12 is an indication for head CT, as more than 80% of these patients will have an injury.**

INTERPRETATION OF HEAD CT SCANS

TBI is a heterogeneous disease with different radiographic patterns of injury, such as skull fracture, EDH, SDH, tSAH, hemorrhagic contusions, focal and diffuse patterns of axonal injury, and cerebral edema. Evaluation of CT scans by a qualified radiologist and prompt (no later than 1 hour) availability of the

■ Table 7-7: Indications for Head CT.

Indications for Head CT	
Age >16 with LOC or PTA (CDC / ACEP)	**Consider CT without LOC or PTA**
GCS < 15	GCS ≤15
Age greater than 60 years	Age >65
Physical evidence of trauma above the clavicle	Coagulopathy, Anticoagulant
Coagulopathy (supra-therapeutic international normalized ratio (INR) or thrombocytopenia)	Focal neurologic deficit
Headache	Severe headache
Vomiting	Vomiting
Drug or alcohol intoxication	Signs of basilar skull fracture
Short-term memory deficit	Ejection from motor vehicle
Posttraumatic seizure	Pedestrian struck by motor vehicle
Focal neurologic deficit	Fall down 5 stairs or >1 meter

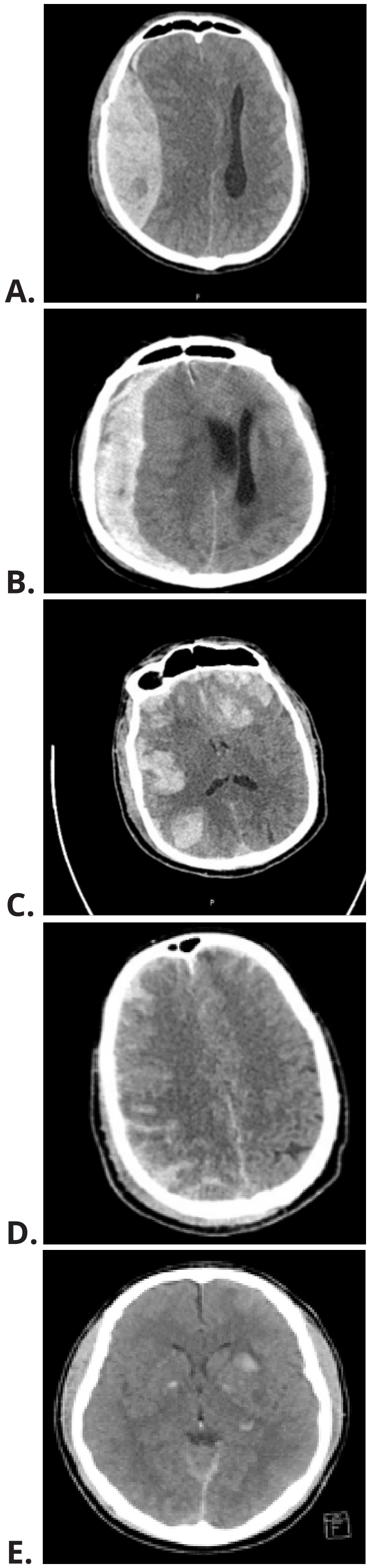
CT, Computed tomography; LOC, Loss of consciousness; PTA, Post-traumatic amnesia; CDC, Centers for Disease Control; ACEP, American College of Emergency Physicians; GCS, Glasgow Coma Score.

Used with permission of Elsevier, from American College of Emergency Physicians Clinical Policies Subcommittee (Writing Committee) on Mild Traumatic Brain Injury, Valente JH, Anderson JD, et al. Clinical Policy: Critical Issues in the Management of Adult Patients Presenting to the Emergency Department With Mild Traumatic Brain Injury: Approved by ACEP Board of Directors, February 1, 2023 Clinical Policy Endorsed by the Emergency Nurses Association (April 5, 2023). *Ann Emerg Med*. 2023;81(5):e63-e105.

results is optimal. Noncontrast CT scan offers valuable insights into ICP status, enabling physicians to initiate timely ICP-lowering strategies, even before transfer to a trauma or neuroscience center.

Acute blood is hyperdense (white) on CT scan images. **Identification of acute hematomas and rapid referral for possible neurosurgical intervention are vital to provide the optimal potential for recovery.** An EDH is lens-shaped and hyperdense. It does not cross the cranial sutures. An SDH is hyperdense, concave (crescent-shaped), and crosses the cranial suture lines. Cerebral contusions are nonuniform, hyperdense lesions of varying size. Contusions may progress in hemorrhage size, amount of associated edema, and clinical impact within hours following injury. tSAH is the presence of blood in the subarachnoid space. The pattern of blood in an aneurysmal SAH is different, typically occupying the basal cisterns. Diffuse axonal injury (DAI) appears as petechial hyperdense images in the subcortical white matter. **■ Figure 7-15** illustrates the appearance of various traumatic intracranial hemorrhage on CT. Brain MRI is a more sensitive imaging modality for diagnosing and evaluating DAI.

■ Figure 7-15: CT Scans of Various Types of Post-Traumatic Intracranial Hemorrhage:
A. Right extradural hematoma. **B.** Right cerebral convexity subdural hematoma **C.** Multiple cerebral contusions. **D.** Traumatic subarachnoid hemorrhage. **E.** Diffuse axonal injury: Deep gray matter and gray-white junction, petechial hemorrhages.



Air has a very low density, appearing black on noncontrast CT. The presence of pneumocephalus (intracranial air) is associated with open skull fracture, craniofacial trauma, and sinus injury.

A noncontrast CT head scan can offer information about ICP. CT signs of critically elevated ICP include the absence or compression of cisterns, midline shifts exceeding 5 mm, and loss of grey-white matter differentiation. **■ Figure 7-16** illustrates CT scan findings of normal and increased ICP. The absence or compression of basal cisterns has a sensitivity of 86% and specificity of 61% for elevated ICP, while a midline shift exhibits a sensitivity of 81% and specificity of 43%.

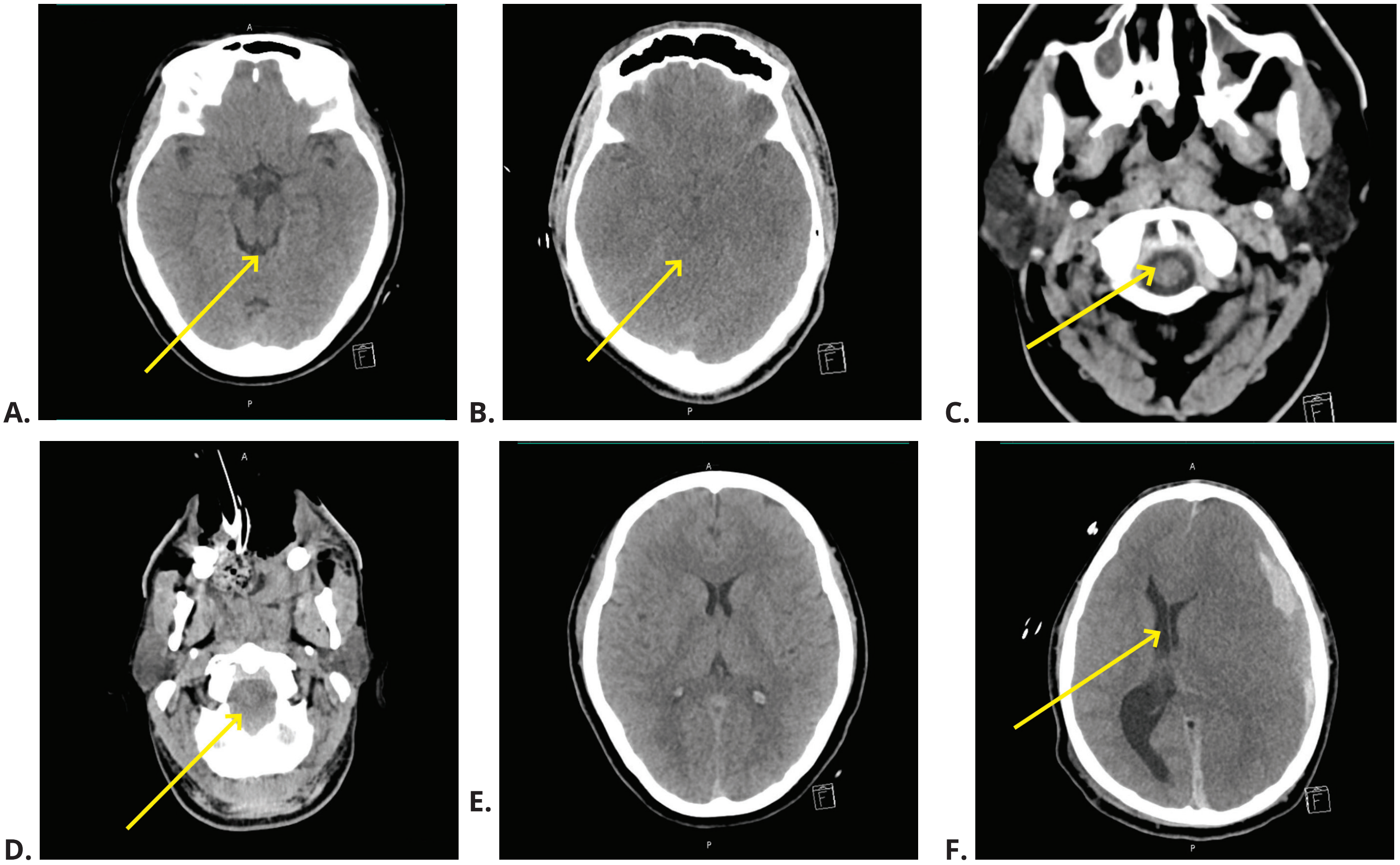
SPINE INJURY

Clinical Clearance of the Cervical Spine

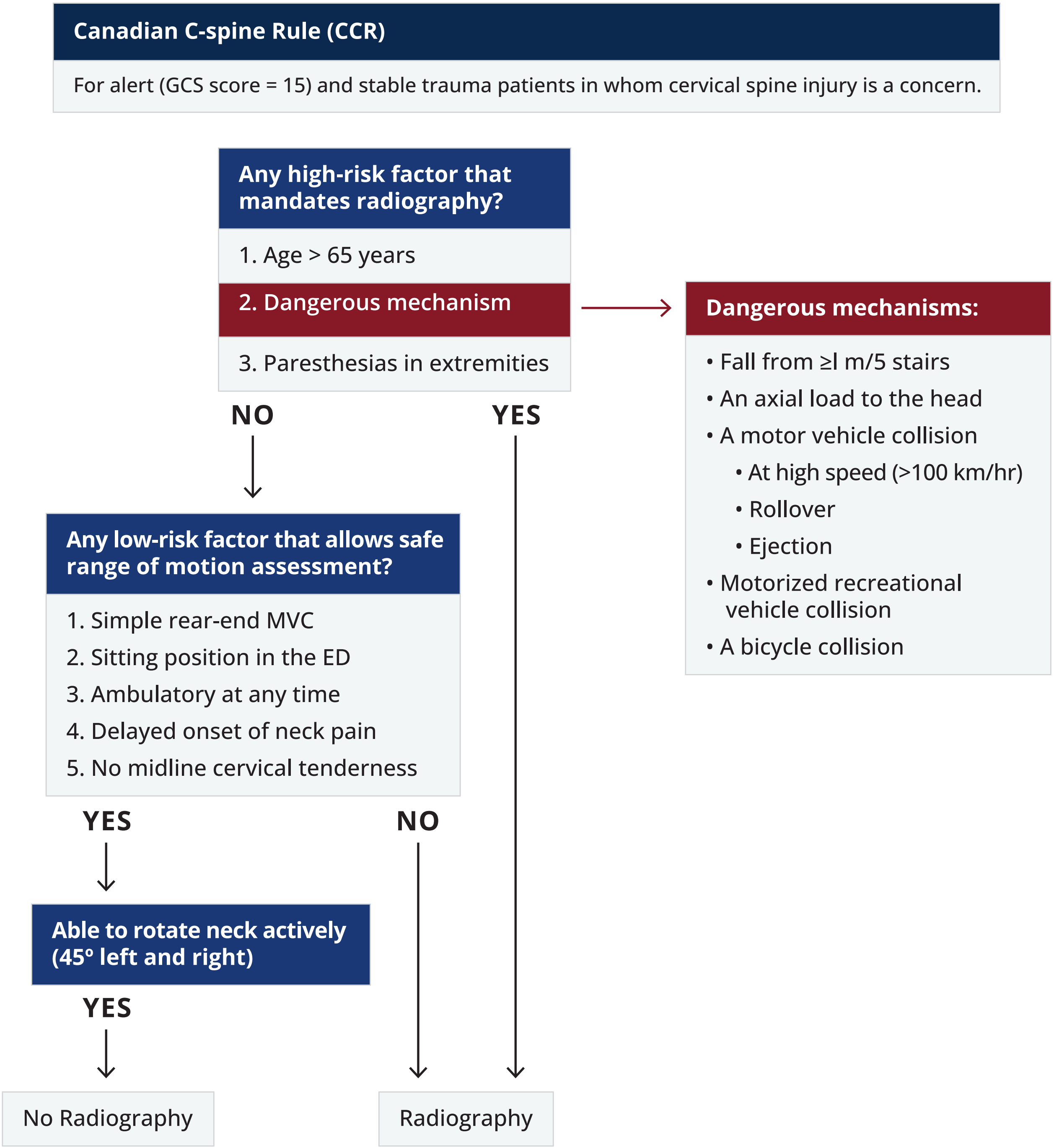
A systematic clinical examination and appropriate radiographic assessment are critical in identifying significant spine injury. **Presence of a neurologic deficit, cervical tenderness, or complaint of neck pain are indications for radiologic imaging. In low-risk scenarios, cervical spine motion restriction by collars and other devices may be discontinued without radiologic imaging following proper application of clinical screening decision tools** such as the Canadian C-Spine Rule (CCR) and the National Emergency X-Radiography Utilization Study (NEXUS) criteria. **■ Figure 7-17** illustrates the CCR. **■ Figure 7-18** illustrates the NEXUS criteria. Described more than 20 years ago, these decision pathways have reported excellent sensitivity if the exclusion criteria are followed. The CCR's exclusion criteria include age > 65 years, GCS < 15, abnormal hemodynamics, and a dangerous mechanism. **CCR and NEXUS criteria are not utilized in pediatric patients and older adults, as limited data exist, and results have demonstrated variable and poor performance.**

If imaging is not indicated according to the NEXUS and CCR criteria, the cervical spine may be cleared clinically by a systematic exam. To perform the examination, the clinician loosens the cervical device, keeping the device attached if possible while an assistant maintains cervical SMR. The clinician palpates the posterior neck. Each vertebra is felt while monitoring for pain. If there is no pain or midline tenderness, the device is removed, and the patient is asked to demonstrate an active (i.e., without

■ Figure 7-16: Some Critical TBI CT Scan Findings: **A.** Arrow points to normal, open basal cisterns. **B.** Arrow points to effaced basal cisterns. **C.** Normal foramen magnum, arrow pointing to a rim of CSF at cervico-medullary junction. **D.** Arrow points to edematous foramen magnum **E.** No midline shift. **F.** Midline shift, arrow pointing to septum pellucidum, and left subdural hematoma.



■ **Figure 7-17: Canadian C-Spine Rule.** A clinical decision tool for cervical spine evaluation. MVC, Motor vehicle collision; ED, Emergency department. Adapted from Stiell IG, Wells GA, Vandemheen KL, et al. The Canadian C-Spine rule of radiography in alert and stable trauma patients. *JAMA*. 2001;286:1841–1848.


Canadian C-spine Rule (CCR)
For alert (GCS score = 15) and stable trauma patients in whom cervical spine injury is a concern.
Any high-risk factor that mandates radiography?
1. Age > 65 years
2. Dangerous mechanism
3. Paresthesias in extremities
Dangerous mechanisms:
• Fall from ≥l m/5 stairs
• An axial load to the head
• A motor vehicle collision
• At high speed (>100 km/hr)
• Rollover
• Ejection
• Motorized recreational vehicle collision
• A bicycle collision
NO
YES
Any low-risk factor that allows safe range of motion assessment?
1. Simple rear-end MVC
2. Sitting position in the ED
3. Ambulatory at any time
4. Delayed onset of neck pain
5. No midline cervical tenderness
YES
NO
Able to rotate neck actively (45° left and right)
YES
No Radiography
Radiography

Adapted with permission of *JAMA*, from The Canadian C-Spine Rule for Radiography in Alert and Stable Trauma Patients, Stiell, Ian G.; Wells, George A., 286, 2001; permission conveyed through Copyright Clearance Center, Inc.

clinician assistance), full range of motion of the neck. Adequate motion involves flexion, extension, and rotation to 45 degrees bilaterally. If the patient denies pain and neurologic symptoms during range of motion, the cervical motion restriction device may be discontinued. If the patient cannot complete a full range of motion, the cervical motion restriction device is continued, and further diagnostic procedures are indicated. In addition, when CT scan is negative for injury and physical examination is reliable, the cervical spine may be cleared following the same method of clinical exam. Specific NEXUS criteria to determine if examination is reliable are listed in ■ **Figure 7-18**.

■ **Figure 7-18: National Emergency X-Radiography Utilization Study (NEXUS) Criteria and Mnemonic.** A clinical decision tool for cervical spine evaluation. Adapted from Hoffman JR, Mower WR, Wolfson AB, et al. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. *N Engl J Med* 2000;343:94–99.

National Emergency X-Radiography Utilization Study (NEXUS) Criteria

Meets ALL low-risk criteria?

1. No posterior midline cervical-spine tenderness and...
2. No evidence of intoxication and...
3. A normal level of alertness and...
4. No focal neurologic deficit and...
5. No painful distracting injuries

YES ↓ **No Radiography**

NO ↓ **Radiography**

NEXUS Mnemonic	
N	**N**euro deficit
E	**E**tOH (alcohol)/intoxication
X	e**X**treme distracting injury/injuries
U	**U**nable to provide history (altered level of consciousness)
S	**S**pinal tenderness (midline)

Explanation:

These are for purposes of clarity only. There are not precise definitions for the individual NEXUS Criteria, which are subject to intepretation by individual physicians.

1. Midline posterior bony cervical spine tenderness is present if the patient complains of pain on palpation of the posterior midline neck from the nuchal ridge to the prominence of the first thoracic vertebra, or if the patient evinces pain with direct palpation of any cervical spinous process.
2. Patients should be considered intoxicated if they have either of the following:
    - A recent history by the patient or an observer of intoxication or intoxicating ingestion.
    - Evidence of intoxication on physical examination, such as odor of alcohol, slurred speech, ataxia, dysmetria or other cerebellar findings, or any behavior consistent with intoxication. Patients may also be considered to be intoxicated if tests of bodily secretions are positive for drugs (including but not limited to alcohol) that affect levels of alertness.
3. An altered level of alertness can include any of the following:
    - Glasgow Coma Scale of 14 or less
    - Disorientation to person, place, time, or events
    - Inability to remember 3 objects at 5 minutes
    - Delayed or inappropriate response to external stimuli
    - Other
4. Any focal neurologic complaint (by history) or finding (on motor or sensory examination).
5. No precise definition for distracting painful injury is possible. This includes any condition thought by the clinician to be producing pain sufficient to distract the patient from a second (neck) injury. Examples may include, but are not limited to:
    - Any long bone fracture
    - A visceral injury requiring surgical consultation
    - A large laceration, degloving injury, or crush injury
    - Large burns
    - Any other injury producing acute functional impairment

Physicians may also classify any injury as distracting if it is thought to have the potential to impair the patient's ability to appreciate other injuries.

Used with permission by Hoffman JR, Mower WR, Wolfson AB, et al. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. *N Engl J Med.* 2000; 343:94–99. permission conveyed through Copyright Clearance Center, Inc.

Methods of Spine Imaging

Multidetector CT with coronal and sagittal reconstructions is the imaging modality of choice to evaluate the cervical and thoracolumbar spine. Plain radiographs have a limited role in the initial evaluation of the spine due to low sensitivity. Cervical spine injuries occur in approximately 10% of blunt TBI patients. Therefore, cervical spine imaging is indicated with moderate to severe TBI. Additionally, **approximately 10% of patients with a cervical spine fracture have a second, noncontiguous vertebral column fracture. Therefore, radiographic evaluation of the entire spine for patients with a cervical spine fracture is appropriate.** The cervical spine is imaged from the craniocervical junction to the cervicothoracic junction, with images formatted in the axial, coronal, and sagittal planes.

When CT technology is unavailable, cervical radiographs visualizing from the occiput to T1, including lateral, Anterior-posterior (AP), and open-mouth odontoid views, are obtained. Adequate radiographs demonstrate the skull base, all seven cervical vertebrae, and the first thoracic vertebra on the lateral view. The shoulders may be pulled caudally to adequately demonstrate the lower cervical spine. If all cervical vertebrae are not visualized on the lateral x-ray film, a "swimmer's view" of the lower cervical and upper thoracic area may be performed. The open-mouth odontoid view visualizes the entire odontoid process, as well as the right and left C1 and C2 articulations. The AP view assists in identifying a unilateral facet dislocation when little or no dislocation is visible on the lateral image. Spine MRI is not generally employed in acute settings; it is requested following the secondary survey and transfer at referral centers by surgical specialists.

Interpretation of Cervical Spine CT Scans

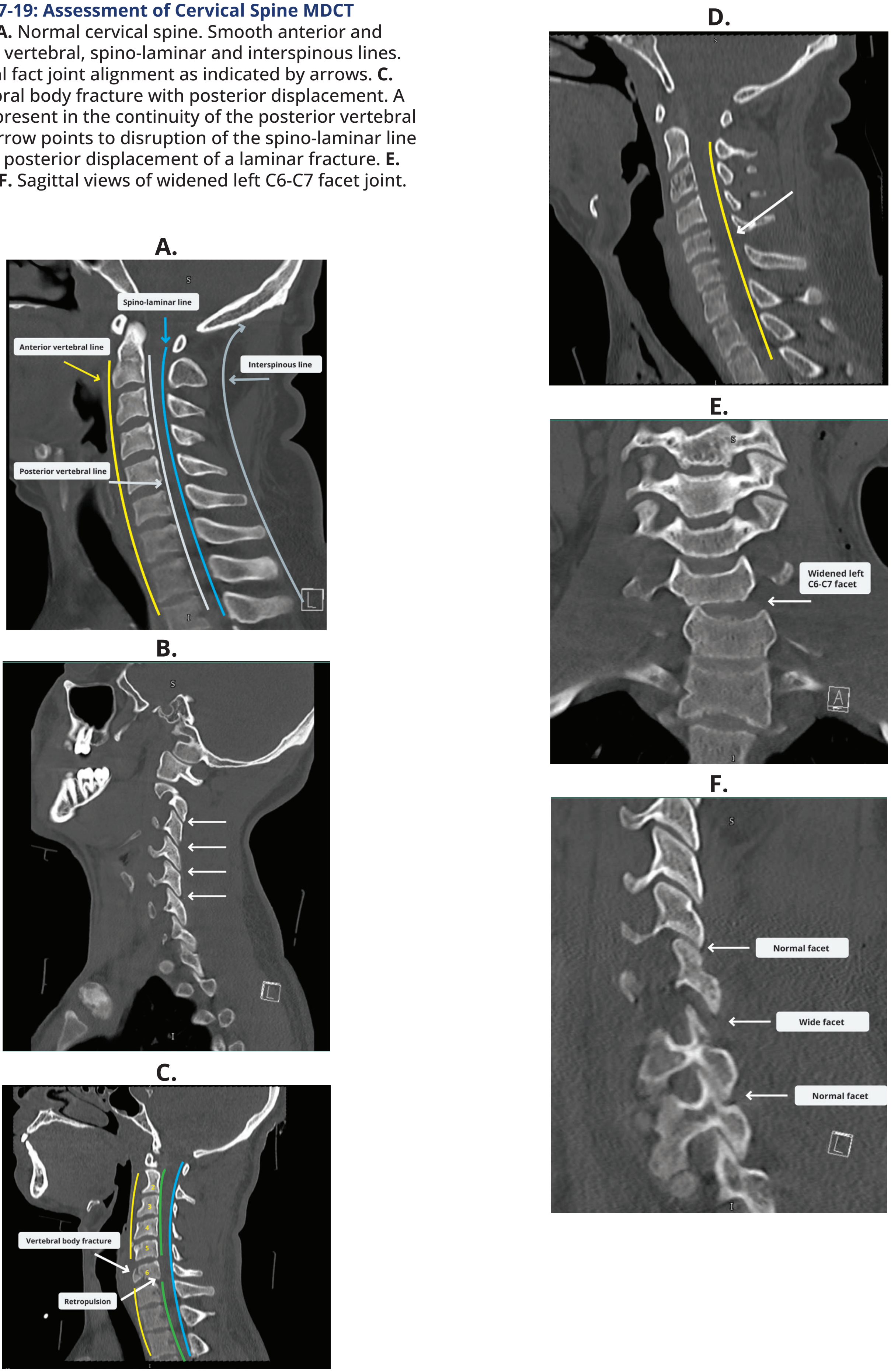
Cervical spinal column injuries may be described by several factors, including stability, location, and mechanism, such as flexion, flexion-rotation, extension, and vertical compression. A two-column approach can be used to assess stability of cervical injury caudal to C2. The anterior column comprises vertebral bodies with intervertebral discs secured by anterior and posterior ligaments. The posterior column, containing the spinal cord, is composed of bilateral laminae and pedicles. ■ **Table 7-8** lists factors in evaluation of cervical spine CT imaging.

Assessment of cervical bone alignment on multidetector CT scans involves delineating the anterior vertebral line (along the anterior vertebral bodies), posterior vertebral line (along the posterior vertebral bodies), spinolaminar line (along the midline of the posterior spinal canal), and interspinous line (along the tips of the spinous processes from C3 to C7). These lines normally form a smooth curve without focal angulation or discontinuity. **Figure 7-19** illustrates these lines of alignment. Examples of cervical fractures detected on CT scan are illustrated in ■ **Figure 7-19** and ■ **Figure 7-20**.

■ **Table 7-8: Two-Column Evaluation of Cervical Spine CT Imaging.**

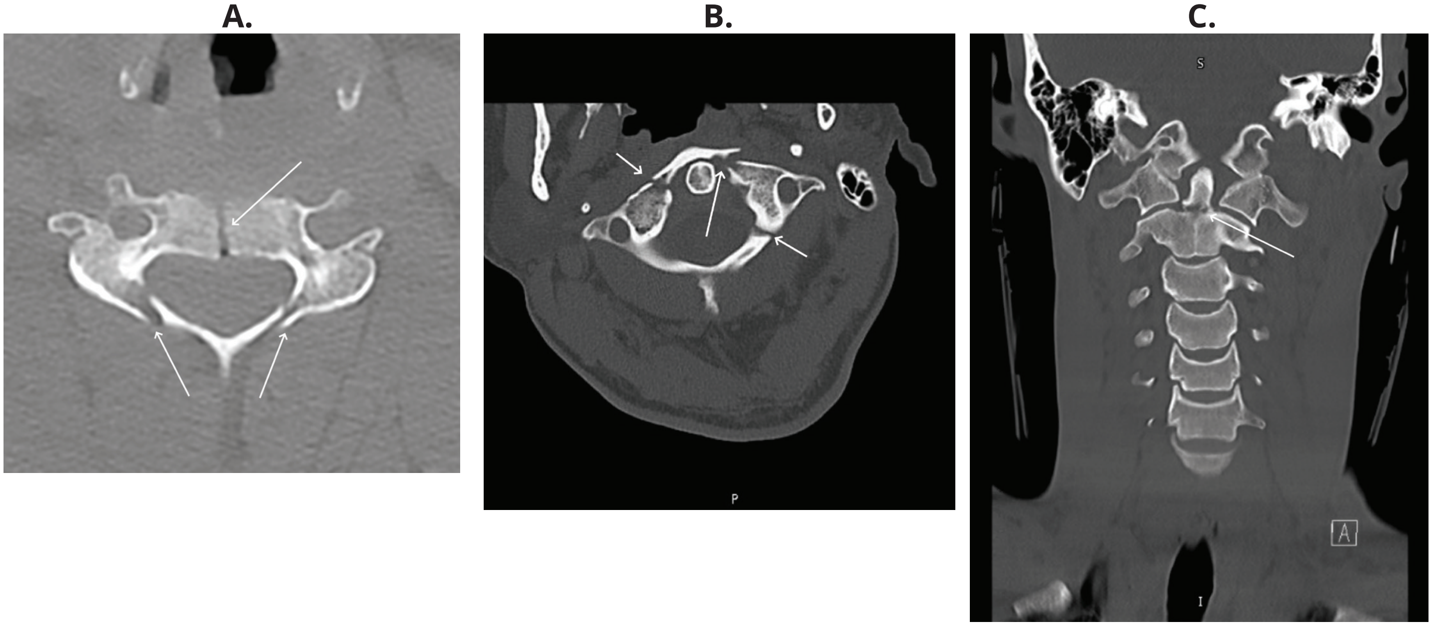
Two-Column Evaluation of Cervical Spine CT Imaging		
Component	**Anterior Column**	**Posterior Column**
Bone	Vertebral body and Transverse process Normal: Preserved body height, no cortical defect Abnormal: Wedging, steps, fractures, retropulsion	Pedicles, lamina, spinous process Normal: All elements intact Abnormal: Fractures
Joints	Intervertebral discs Normal: Disc space symmetrical Abnormal: Focal narrowing, or asymmetry assessed in sagittal and coronal planes	Facet joint Normal: Bilateral symmetrical, parallel Abnormal: Asymmetry, diastasis, subluxation, dislocation
Ligaments	AVL /PVL Normal: Aligned Abnormal: Anterior or posterior translation of vertebrae Asymmetric disc space widening	Posterior ligamentous complex: Interspinous ligaments, ligamentum flavum Normal: Aligned, smooth interspinous line Abnormal: Anterolisthesis, focal kyphosis, abrupt interspinous widening, facet joint asymmetry or diastasis
Curvature	Normal: Smooth lordosis Abnormal: Focal kyphosis	Normal: Smooth lordosis Abnormal: Focal kyphosis
Alignment	Smooth, uninterrupted anterior and posterior vertebral lines visualized in sagittal plane	Smooth, uninterrupted spino-laminar and Interspinous lines visualized in sagittal plane Uninterrupted articular pillar alignment in sagittal and coronal planes

CT, Computed tomography; AVL, Anterior vertebral line; PVL, Posterior vertebral line.


D.
A.
Spino-laminar line
Anterior vertebral line
Interspinous line
Posterior vertebral line
E.
Widened left C6-C7 facet
B.
F.
Normal facet
Wide facet
Normal facet
C.
Vertebral body fracture
Retropulsion

■ **Figure 7-19: Assessment of Cervical Spine MDCT Images:** **A.** Normal cervical spine. Smooth anterior and posterior vertebral, spino-laminar and interspinous lines. **B**. Normal fact joint alignment as indicated by arrows. **C.** C6 vertebral body fracture with posterior displacement. A break is present in the continuity of the posterior vertebral line. **D.** Arrow points to disruption of the spino-laminar line following posterior displacement of a laminar fracture. **E.** Coronal. **F.** Sagittal views of widened left C6-C7 facet joint.

■ **Figure 7-20: Cervical Spine Fractures. A.** Posterior arrows point to bilateral C7 laminar fractures, Anterior arrow points to vertebral body fracture. **B.** Jefferson fracture: Fracture of both anterior and posterior arches of C1 as shown by arrows. **C.** C2, Odontoid process fracture at arrow.

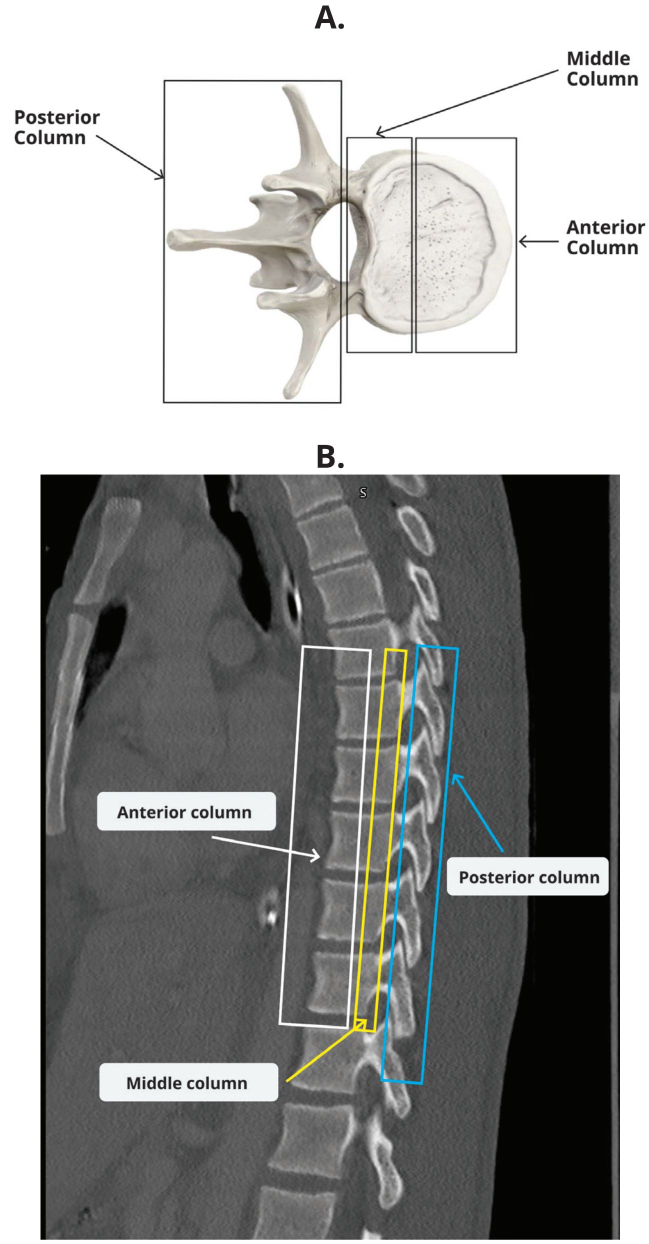


The thoracic and lumbar spine can be evaluated as three parallel vertical columns. ■ **Table 7-9** lists the three columns. ■ **Figure 7-21** illustrates the three columns. Stability is based on integrity of two of the three columns. However, few studies have reported on the validity of this three-column stability assessment. Examples of thoracic and lumbar fractures detected on CT scan are illustrated in ■ **Figure 7-22**.

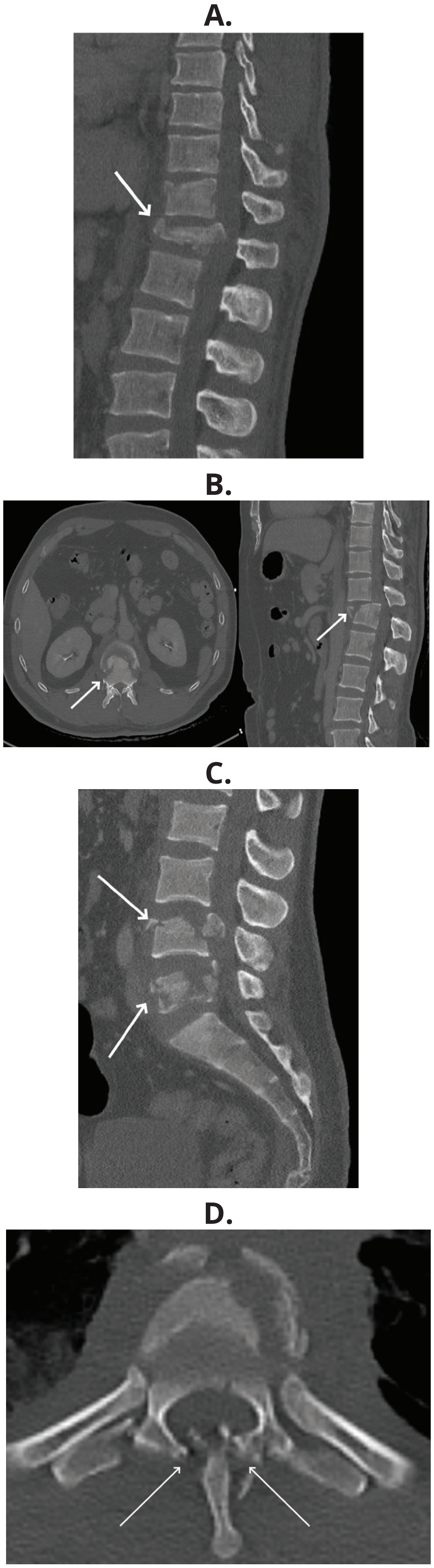
■ **Table 7-9: Three-Column Evaluation of Thoracic and Lumbar Spine CT Imaging**

Three-Column Evaluation of Thoracic and Lumbar Spine CT Imaging		
Anterior column	**Middle column**	**Posterior column**
Anterior Longitudinal ligament (ALL) Anterior two-thirds of the vertebral body Anterior two-thirds of the intervertebral disc	Posterior one-third of the vertebral body Posterior one-third of the intervertebral disc Posterior longitudinal ligament (PLL)	Structures posterior to PLL Pedicles Facet joints and articular processes Ligamentum flavum Neural arch and interconnecting ligaments

■ **Figure 7-21: Three-Column Evaluation of Thoracolumbar Spine CT Images. A.** The three columns on a single vertebra.
B. The three columns on a sagittal CT image.


A.
Middle Column
Posterior Column
Anterior Column
B.
S
Anterior column
Posterior column
Middle column

■ **Figure 7-22: Thoracic and Lumbar Spine Fractures. A.** T 12 fracture at arrow. **B.** L1 compression fracture with retrolisthesis and spinal canal stenosis on CT images as indicated by arrows. **C.** L4 and L5 burst fractures at arrows. **D.** Fracture bilateral laminas and body of T6 as shown at arrows.



Magnetic Resonance Imaging

MRI provides information regarding soft tissues and ligamentous injury. MRI can visualize spinal cord structures, nerve roots, discs, and ligaments. MRI may be obtained to further define injuries, to diagnose injuries not visualized on CT when the exam is abnormal, and for operative planning per a surgical specialist. MRI is not obtained during the initial assessment process.

BLUNT CEREBROVASCULAR INJURY

Although rare, untreated blunt cerebrovascular injury (BCVI) may have devastating consequences. Therefore, when a cervical spine injury is detected, either CT or magnetic resonance angiography is performed to evaluate for BCVI. Traditional BCVI screening criteria miss about 20% of injuries, many of which are clinically significant. Current recommendations are to perform a CT angiography of the neck for any patient with significant mechanism of injury for which head and cervical spine CTs are obtained. Examples of indications to evaluate for BCVI are listed in ■ **Table 7-10**.

■ Table 7-10: Recommended Screening Criteria for BCVI.

Recommended Screening Criteria for BCVI
Criteria
• Head or cervical CT performed due to mechanism
• Scalp degloving injury
• Severe TBI with GCS <6
• TBI with thoracic injuries
• Neurological exam findings not explained by neuroimaging
• Focal neurological deficit (transient ischemic attack, hemiparesis, vertebrobasilar symptoms, oculosympathetic palsy/Horner Syndrome)
• Cerebral ischemia or vascular territory edema on CT or MRI
• Base of skull fracture with involvement of the carotid canal or petrous temporal bone
• Complex skull fracture (e.g., involving frontal or other sinuses, orbit)
• Le Fort II or III fracture pattern
• Mandible fracture
• Cervical spine fracture
• Arterial hemorrhage from the neck, nose, or mouth
• Neck soft-tissue injury (e.g., seatbelt sign, hanging, hematoma)
• Near hanging with hypoxic-ischemic (anoxic) brain injury
• Clothesline type injury or seat belt abrasion with significant swelling, pain, or altered mental status
• Crepitus, soft tissue of neck
• Cervical bruit in patients <50 years of age
• Upper rib fractures
• Thoracic vascular injuries
• Blunt cardiac rupture

BCVI, Blunt cerebrovascular injury; TBI, Traumatic brain injury; GCS, Glasgow coma score; CT, Computerized tomography; MRI, Magnetic resonance imaging.

LABORATORY ADJUNCTS TO ASSESSMENT

Lab investigations for TBI include a total blood count, platelet count, clotting profile, and biochemistry analysis with lactate levels. **Assessment of INR in scenarios of preinjury warfarin therapy is critical. A goal of treatment is an INR ≤ 1.4.** Arterial blood gas analysis, if available, is evaluated at regular intervals to assess hypoxemia and hypercarbia. When available, point-of-care viscoelastic monitoring can evaluate coagulation status. Pending availability, brain injury biomarkers—such as glial fibrillary acidic protein (GFAP), ubiquitin carboxy-terminal hydrolase L1 (UCH-L1), and S100 calcium binding protein (S100B)—are being evaluated as criteria for brain CT imaging in selected suspected TBI scenarios.

ADJUNCT NONINVASIVE ASSESSMENT OF ICP

Optic nerve sheath diameter measurement is an ultrasonography technique to assess the diameter of the optic nerve sheath, which is continuous with the meninges of the central nervous system and reflects changes in intracranial compliance and ICP. Optic nerve sheath diameter can be measured at the bedside. Limitations include technical expertise, availability, and lack of consensus on the optimal threshold for diagnosing elevated ICP.

INTERVENTIONS AND TREATMENTS

Rapid appropriate management of TBI and SCI increases the probability of survival, prevents secondary damage, and reduces long-term disability. Hypoxia and hypotension are particularly harmful and increase the risk of death. The main goal of managing TBI and SCI is to mitigate the impact of secondary injury, thereby reducing the progression of neuronal damage.

PREHOSPITAL

Hypoxia has a significant deleterious effect on outcomes in TBI. While any episode of hypoxia is treated, prevention is critical. When available, oxygen is administered in the prehospital environment for all patients. SpO_2 is maintained at ≥ 94%. Additional airway interventions are performed as indicated. A nasopharyngeal airway is not inserted with signs of basilar skull fracture, facial trauma, or disruption of the midface, nasopharynx, or roof of mouth. To maintain adequate ventilation and oxygenation, and due to frequent associated severe injuries, prehospital intubation and mechanical ventilation may be performed when GCS is below 9 if experienced prehospital professionals are present and following local guidelines. Depending upon local circumstances, intubation may be deferred until hospital arrival. Prehospital time is minimized while ensuring adequate oxygenation.

HOSPITAL

The xABCDE approach to resuscitation is performed. When available, early involvement of specialized neurotrauma services is advised. **Prevention of further neurologic damage is enhanced by providing adequate blood flow and oxygenation to the brain and spinal cord.** Hypoxia, hypotension, and ventilation derangements are prevented. **Oxygenation and blood pressure**

goals are higher than in scenarios without potential neurologic injury. For adults with TBI, a systolic blood pressure of at least 100 mm Hg is recommended. ■ **Table 7-11** lists blood pressure goals for TBI and SCI.

■ **Table 7-11: Blood Pressure Goals for TBI and SCI.**

Blood Pressure Goals for TBI and SCI		
Ages	**TBI**	**SCI**
15 years and older	SBP ≥ 100 mm Hg	MAP >90 mm Hg
Less than 15 years	SBP > 5th percentile for age [70 mm Hg + (age * 2)]	

TBI, Traumatic brain injury; SCI, Spinal cord injury; SBP, Systolic blood pressure; MAP, Mean arterial pressure.

Target SpO_2 is ≥94%. When able to be monitored, $ETCO_2$ is maintained at 35–40 mm Hg. In scenarios of concomitant TBI and SCI, the TBI blood pressure targets are followed. **Hypothermia is avoided.** Target INR is ≤1.4. Goals for other laboratory and monitoring values are listed in ■ **Table 7-12**.

AIRWAY AND BREATHING

Even a single, brief episode of hypoxia is associated with increased TBI mortality. Endotracheal intubation to maintain oxygenation and ventilation is indicated if GCS is ≤8. Agitation and declining neurologic status are additional indications to consider intubation, as is an SCI proximal to the C5 level or associated with refractory hypoxemia. **Airway manipulation is performed with manual motion restriction of the head and neck.** The anterior portion of a cervical collar may be removed or loosened to allow for wider mouth opening and adequate visualization of the vocal cords during laryngoscopy. Both facemask ventilation and intubation can be challenging due to limitations in neck movements and concurrent facial injuries. Intubation is optimally performed by an experienced clinician skilled in advanced difficult airway management. If intubation fails, a surgical airway is performed, as discussed in *Chapter 4, Airway Assessment and Management.*

CIRCULATION

Hypotension has a detrimental effect on the outcome of both head and spinal cord injuries. The combined effect of hypotension and hypoxia increases the risk of death by two-fold in patients with head injuries. Permissive hypotensive resuscitation is avoided in scenarios of SCI and moderate

■ **Table 7-12: Optimal Values in TBI Management**.

Optimal Values in TBI Management		
Category	**Parameter**	**Optimal Value**
Clinical Parameters	Systolic blood pressure	≥100 mm Hg
	Mean arterial pressure	>80 mm Hg
	Temperature	36–38°C
	Pulse oximetry	≥94%
Laboratory Parameters	Glucose	100–180 mg/dL
	Hemoglobin	> 7 g/dl
	International normalized ratio (INR)	≤1.4
	Serum sodium	135–145 meq/dL
	Serum osmolality	≤320 mOsm
	PaO_2	80–100 mm Hg
	$PaCO_2$	35–45 mm Hg
	pH	7.35–7.45
	Platelets	≥75 X 103 mm^3
Neurologic Monitoring Parameters	Cerebral perfusion pressure	60–70 mm Hg*
	Intracranial pressure	<22 mm Hg*
	$PbtO_2$	≥15 mm Hg

TBI, Traumatic brain injury; PbtO2, Partial brain tissue oxygenation.

to severe TBI. Blood products are transfused for volume resuscitation. When blood products are not available, isotonic fluid such as normal saline is safe in maintaining volume status in head injury patients. **However, blood is preferred.** A recent study demonstrated that using balanced crystalloid solutions was associated with a worse discharge disposition. Hypotonic solutions containing dextrose are avoided due to the risk of worsening cerebral edema. Hypertonic solution for prehospital resuscitation of TBI patients with hypotension is not superior to normal saline. Patients who remain hypotensive after blood and/or fluid resuscitation may be administered a vasopressor to achieve blood pressure targets. Phenylephrine and norepinephrine are two common options.

NEUROGENIC SHOCK

Neurogenic shock may occur following a SCI proximal to the T6 level. Treatment is initiated to ensure adequate vascular volume. Blood products are administered to treat blood loss. Crystalloid solutions are used once adequate hemorrhage control is obtained and resuscitation completed. **In scenarios of isolated SCI, a MAP of 85–90 mm Hg is currently recommended to be maintained for seven days. If fluid resuscitation fails to achieve goals, vasopressors are added.** Norepinephrine is an option, as α-1 and β-1 activity will improve peripheral vasoconstriction, heart rate, and contractility. Phenylephrine may also be administered for SCI caudal to T6. However, as phenylephrine lacks β-1 activity, bradycardia may be exacerbated in scenarios of injury proximal to T6. **Vasopressors are optimally administered via central venous access.** However, in emergent situations, vasopressors may be infused through a peripheral IV.

TRANSFUSION GOALS AND COAGULOPATHY

Replacing blood loss with blood or blood products is optimal. Simultaneous replacement of clotting factors potentially reduces progression of cerebral contusions. Transfusion strategies for treatment of hemorrhagic shock are discussed in *Chapter 6, Circulation Assessment and Volume Resuscitation*. Following TBI or SCI, a hemoglobin level of ≥7 g/dL is recommended to be maintained.

Coagulopathy occurs in 25% to 30% polytrauma patients and is promptly corrected in TBI and SCI. About one-third of all brain injuries expand in the first hours following injury, some due to delays in treatment or inappropriate correction of coagulation defects. It is unknown if TBI has distinct mechanisms that result in coagulopathy or if clotting abnormalities are due to general trauma-induced coagulopathies. **The presence of preinjury anticoagulants and/or antiplatelet agents is common, particularly in older adults. Rapid determination of the presence of these medications and reversal of the clot-inhibiting effects are vitally important in the presence of TBI and SCI. Table 6-7** in *Chapter 6, Circulation Assessment and Volume Resuscitation* lists various clot-inhibiting medications and methods to reverse their effects. The management of hemorrhage-induced and medication-induced coagulopathies is similar to their management without neurologic injury (*see Chapter 6, Circulation Assessment and Volume Resuscitation*). The benefit of routine platelet transfusion is debated for TBI patients receiving antiplatelet agents and with a normal platelet count. **Platelet transfusion is indicated if neurosurgical intervention is to be performed. To promote clot formation and stability, therapeutic goals include an INR <1.5, a platelet count ≥75 × 10^3 per mm^3, normothermia, and a normal pH.**

Tranexamic Acid

For patients with moderate to severe TBI who present within 3 hours of injury, IV administration of TXA, either a single 2-g dose or a 1-g dose over 10 minutes followed by IV infusion of 1 g over 8 hours, is safe and may decrease mortality. The administration of TXA might be reasonable for other subgroups, such as severe TBI with bilateral reactive pupils and mild TBI with intracranial bleeding, but the benefit remains uncertain.

ANALGESIA AND SEDATION

Intubated TBI patients receive intravenous analgesia and sedation for pain and agitation. Adequate sedation and analgesia reduce oxygen consumption and CBF, decreasing cerebral fluid volume and reducing ICP. Appropriate sedation enhances ventilator synchrony and may mitigate sympathetic responses, preventing hypertension and tachycardia. **Short-acting agents such as propofol or fentanyl are preferred to allow regular neurological examinations** and detect a decline in neurologic function. Hypotension is a common sequela of propofol bolus or infusion. Frequent blood pressure and hemodynamic monitoring are essential during propofol administration. Some clinicians utilize ketamine due to a proposed neuroprotective effect through N-methyl-D-aspartate (NMDA) receptor antagonism. Ketamine has favorable pharmacological characteristics without an adverse effect on ICP. Thus, ketamine is a reliable anesthetic agent for RSI in prehospital environments.

CRITICAL NEUROWORSENING

Critical *neuroworsening* is a term to describe a rapid deterioration of neurologic status that warrants emergent evaluation and evaluation. The clinical signs are a spontaneous decrease in the GCS motor score, new decrease in pupillary reactivity, new pupillary asymmetry, bilateral dilated pupils, new focal motor deficit, and Cushing's triad (widened pulse pressure, bradycardia, and irregular respiration). Causes of deterioration are numerous and include expanding intracranial mass lesions and cerebral edema. **If signs of neuroworsening are present, presumptive treatment is initiated without delay.** CT scan of the brain is repeated to ascertain the cause of neuroworsening.

HYPEROSMOLAR THERAPY

Hyperosmolar therapy is the central pharmacological therapy for management of intracranial hypertension and critical neuroworsening. Hyperosmolar therapy has a biphasic mechanism of action. Initially, a hyperosmolar solution bolus boosts cardiac output, raising blood pressure and CPP. If autoregulation is intact, cerebral vasoconstriction occurs, reducing cerebral blood volume and ICP. The solution creates an osmolar gradient for water to cross the blood-brain barrier, lowering brain volume and ICP. **Mannitol and hypertonic saline solutions are commonly used hyperosmolar agents. ■ Table 7-13** lists hyperosmolar agents.

Table 7-13: Hyperosmolar Agents.

Hyperosmolar Agents		
Agent	**Dose**	**Comments**
Mannitol	20% Solution: IV bolus, 1 g kg (5 ml / kg) over 5–15 min Can repeat every 4–6 hours	ICP decreases in 1–5 min with peak effect in 20–60 minutes May aggravate hypotension through osmotic diuresis
Hypertonic saline	5% Solution: 2.5–5 mL kg over 5–20 min Pediatric: 2–5 mL/kg over 10–20 min 7.5% Solution: 1.5 –2.5 mL/kg over 5–20 min 23.4% Solution: 30 ml over 10–20 min Pediatric: 0.5 mL kg (max dose: 30 mL)	Ideally administered through a central venous catheter In the emergent situation, administration via peripheral IV is safe Monitor for subcutaneous infiltration

Although hypertonic saline has physiological advantages over mannitol, there's no evidence that either is more effective in improving neurological outcome. Hyperosmolar agents will increase serum sodium and osmolality levels. These values are monitored frequently to avoid serious complications. When the serum sodium is above 160 mEq/L or osmolality is above 320 mOsm, additional hyperosmolar therapy is unlikely to be effective.

STEPWISE MANAGEMENT OF NEUROWORSENING

Endotracheal intubation and controlled mechanical ventilation are instituted unless already performed. **The head is elevated 30° to 45°, while maintaining neutral cervical spine position to ensure adequate venous return from the brain.** In scenarios of a potential unstable spine, a reverse Trendelenburg position may be employed. The cervical collar is examined to assess if it is applied too snugly. Endotracheal tube fixation is similarly examined for potential compression of the jugular veins.

Transient emergent hyperventilation to a target $PaCO_2$ or $ETCO_2$ of 30–35 mm Hg is performed as a lifesaving measure. Hyperventilation quickly decreases ICP during cerebral herniation. Prolonged hyperventilation is not recommended and may increase ischemic events.

Analgesia and sedation are optimized. An IV bolus of hypertonic saline 5% (250 mL) or mannitol 20% (250 mL) is administered. Normothermia is maintained with a core temperature of 36°C–37.4°C via warming or cooling systems, as indicated. **Surgical evaluation is performed** for potential evacuation of mass lesions or decompressive craniectomy.

SURGICAL MANAGEMENT FOR TBI

Neurosurgical interventions in TBI include invasive ICP monitoring, external ventricular drain insertion, intracranial hematoma evacuation, and decompressive craniectomy. If ICP monitoring is available, it is often performed in scenarios of postresuscitation GCS 3–8 associated with an abnormal CT scan (e.g., presence of hematomas, contusions, swelling, herniation, or compressed basal cisterns).

Indications for Surgical Interventions in TBI

A neurosurgeon will discuss the risks and benefits of operative therapy considering the specific clinical scenario with the patient's decision-maker(s). Even if a relatively high GCS score is present, evacuation of a large (> 25 mL) traumatic hematoma may be recommended before neurological deterioration develops from hematoma enlargement or brain swelling. A lower threshold for surgical intervention may apply to posterior fossa lesions. Specific indications for surgical intervention include an acute SDH with > 10 mm thickness or associated with >5 mm midline shift; an acute SDH of any size when associated with decline in GCS of at least 2 points or associated with asymmetric or nonreactive pupils; an acute EDH with volume >25 mL, with >15 mm thickness, or associated with either a >5 mm midline shift or a GCS of ≤8; cerebral contusions associated with GCS ≤8 and midline shift >5 mm or herniation; and a cerebellar hemorrhage >3 cm in diameter or resulting in mass effect, brainstem compression, or hydrocephalus. Following evacuation of a cerebral hematoma, the removed portion of skull may not be immediately replaced to allow decompression of edematous brain.

Open Skull Fractures

Depressed skull fractures and the depth of the depression are measured by CT scan. Generally, surgical elevation is considered if fracture displacement is greater than the thickness of the skull, as well as for contaminated wounds. Perioperative antibiotics are recommended. More than 24 hours of antibiotic treatment is limited to severely contaminated wounds. Nondepressed open fractures with minimal soiling are generally adequately managed with irrigation and closure of the overlying tissue defect with one dose or a maximum of 24 hours antibiotic therapy.

Decompressive Craniectomy

Decompressive craniectomy is a rescue therapy for patients with elevated ICP refractory to medical management. Decompressive craniectomy has been demonstrated to reduce mortality and improve outcome over 24 months. The RESCUEicp trial predicted that if 100 patients are treated with secondary decompressive craniectomy, compared to nonoperative management, there will be 21 extra survivors with the following functional outcomes: one-third independent outside the home, one-third independent in the home, and one-third dependent.

SURGICAL MANAGEMENT FOR SPINAL INJURIES

Early spinal decompression and stabilization is frequently performed in experienced centers and may result in improved functional recovery. Surgery may need to be delayed until respiratory and hemodynamic stability is achieved. Several studies with early cord decompression and spine fixation performed within 8–24 hours of injury showed improved functional outcomes. Early surgery decreases additional injury from cord compression and allows for early mobilization, reducing the rate of pulmonary complications, pressure ulcers, and venous thromboembolism.

OTHER MANAGEMENT CONSIDERATIONS

ELECTROLYTES, GLUCOSE, AND NUTRITION

Due to fluid shifts from injury and osmolar therapy, electrolyte management is vital. Sodium levels are maintained within the range of 135–145 mEq/L unless active hyperosmolar therapy is employed. Avoidance of hyponatremia is very important to prevent exacerbation of cerebral edema. Frequent monitoring of serum sodium levels may be necessary. TBI patients can develop diabetes insipidus (DI) or the syndrome of inappropriate antidiuretic hormone (SIADH) / cerebral salt-wasting syndrome. Osmolality is measured frequently when mannitol is used as an osmotic agent.

Both hyperglycemia and hypoglycemia have detrimental effects on outcomes. Serum glucose levels are maintained in the range of 100–180 mg/dL. Protein and energy deficits are common during hospitalization following TBI. Nutritional support is essential to prevent the development of malnutrition and to blunt the catabolic effects of TBI. Enteral nutrition is initiated once a patient is hemodynamically stable, ideally within 24–72 hours of injury, reaching full supplementation within 7 days of injury. Postpyloric feeding access is preferred if it can be obtained rapidly without delaying initiation of feeding. Consideration for parenteral support is recommended when enteral nutrition is contraindicated.

SEIZURE PROPHYLAXIS AND TREATMENT

TBI severity is correlated with early (i.e., within 7 days) post-traumatic seizures. The highest incidence is following penetrating injury. Therefore, prophylactic antiseizure medication is recommended following severe (GCS ≤8) and penetrating TBI. Indications following blunt, moderate TBI include depressed skull fracture, SDH, cortical contusion, extradural (epidural) hematoma, intracerebral hematoma, and occurrence of seizures within 24 hours of injury. In contrast, prophylactic antiseizure medication is not recommended in scenarios of a GCS of 14–15 with or without intracranial bleeding, isolated tSAH, isolated traumatic IVH, and isolated SDH with GCS ≥13. The benefit of antiseizure medication in a particular scenario is evaluated against the risk of producing impaired cognition, particularly in older patients.

The choice of antiseizure medication depends on availability. The most studied drugs include phenytoin, fosphenytoin, valproic acid, and levetiracetam. **Phenytoin has been utilized for decades. Levetiracetam and lacosamide, may have equivalent efficacy for seizure prevention with fewer adverse events** and possibly better functional outcomes. Valproic acid (compared to phenytoin) for early PTS prophylaxis is associated with an increased risk of death and is not utilized. Prophylactic antiseizure medication is stopped within 7 days unless seizures have occurred >24 hours postinjury or it was a preinjury medication. Prolonged administration does not decrease the risk of seizures after the first week. In pediatric cases, either levetiracetam or (fos)phenytoin is appropriate for 7 days. Levetiracetam has fewer adverse interactions, and therapeutic drug monitoring is not needed. Commonly used levetiracetam doses are 10–20 mg/kg twice daily.

VENOUS THROMBOEMBOLISM PROPHYLAXIS

TBI and SCI patients are at high risk of venous thromboembolism. Mechanical prophylaxis with intermittent pneumatic compression is started on admission, when available. Chemical thromboprophylaxis with low-molecular-weight heparin (the preferred agent) can be started within 24–48 hours of injury if the repeated head CT scan demonstrates no progression of injury and if probability of intracranial or spinal operation is low.

TREATMENTS TO AVOID

Prophylactic hyperventilation with $PaCO_2$ <30 mm Hg in the first 24 hours of injury is avoided unless clinical signs of brain herniation exist. In a herniation scenario, hyperventilation with an $ETCO_2$ target of 30–35 mm Hg may be used as a temporary bridge to definitive treatment. Neither scheduled hyperosmolar therapy (i.e., not directed to treat an ICP increase) nor furosemide are recommended to treat cerebral edema. **Routine steroid administration is not indicated for the management of either TBI or SCI patients.** Steroids may increase mortality and are associated with gastrointestinal disorders, hyperglycemia, and infection. However, in selected partial SCI scenarios, steroid treatment may be recommended by a specialist. There are no proven pharmacological agents to reduce the impact of SCI.

Prophylactic or therapeutic hypothermia does not reduce secondary injury or improve outcomes. However, fever is treated promptly with medication and/or external temperature management. Prophylactic antibiotics are not administered unless there is a penetrating brain injury or contamination of an open wound. Antibiotic prophylaxis is not recommended in instances of skull fracture with pneumocephalus or CSF leak. High dose propofol for burst suppression and routine increase of CPP to > 90 mm Hg are not recommended.

REASSESSMENT

TRAUMATIC BRAIN INJURY

Reassessment is conducted at least hourly, and repeated imaging occurs at regular intervals to promptly detect adverse changes. The Consensus Revised Imaging and Clinical Examination Protocol and Seattle International Severe Traumatic Brain Injury Consensus Conference encourage monitoring of minor (clinical) and major (imaging) criteria to define whether escalation of medical and/or surgical therapy is indicated. This recommendation is applied in moderate TBI scenarios due to the possibility of deterioration in the first hours after injury. If neuroworsening is detected (see the previous section, Critical Neuroworsening), a repeat CT scan is promptly considered after clinical reevaluation and followed by medical and/or surgical treatment of the cause (see the aforementioned Stepwise Management of Neuroworsening).

SPINAL INJURY

Frequent reassessment of a patient with SCI is essential. Due to acute cord edema, the functional level of cervical SCI may move cranially in the first several hours following injury. Respiratory function may decline, and respiratory failure ensue, prompting intubation and mechanical ventilatory support. Hypotension due to any shock can worsen cord injury. Therefore, hypotension and hypoxia are promptly addressed. If available, transfer to a neuroscience center is accomplished as soon as feasible. Occasionally, a skeletally unstable spinal column injury without neurologic deficit can become displaced, with potential development of a spinal cord defect. **Early detection of new neurologic symptoms is important to potentially prevent further neurologic impairment.** The ASIA chart is a valuable tool to track injury progression or clinical instability over time. ■ **Figure 7-13** illustrates the ASIA worksheet.

SPECIAL POPULATION CONSIDERATION

TRAUMATIC BRAIN INJURY

Physiology, response to injury, management, and prognosis of TBI vary across ages and populations. Some of these unique populations are covered in greater detail in accompanying chapters (see *Chapter 11, Trauma in the Pediatric Patient*).

Assessment may be challenging for the very young and, on occasion, for older adult trauma patients. Different assessment methods may be beneficial (e.g., pediatric GCS in children; consideration of preexisting cognitive, hearing, or visual impairment in older adults). Physiological parameters for children vary by age. Heart rate, blood pressure, and ventilation targets are adjusted to be appropriate for age and size. For older adults, preinjury medical conditions and medications may influence target blood pressure, heart rate, and oxygen saturation.

From birth to 4 years of age, assaults are the leading cause of TBI. Therefore, in the absence of a history of a high-velocity injury such as a motor vehicle crash or fall from height, an inflicted injury is a potential etiology in a young child with a severe TBI.

Surgical principles for young children with TBI differ from those of older children and adults. Asymptomatic epidural hematomas in children and depressed fractures in infants may be managed without surgery. Low-velocity fractures of the parietal skull may spontaneously remodel due to brain growth.

Mortality rates for TBI patients older than 74 years are more than two times higher than those younger than 74 years. Older adults are often injured by falls. Sometimes, an apparently minor mechanism may result in a clinically significant TBI. Anticoagulant and antiplatelet therapy complicate management. A CT scan is obtained more frequently in older adults, particularly when preinjury cognitive impairment complicates clinical assessment. Although the prognosis for those over 75 years of age with severe TBI is poor, age alone is not a deciding factor in the intensity of therapy.

SPINAL INJURY

Traumatic spinal cord and spinal column injury in children are uncommon, accounting for less than 10% of all spinal cord damage in those under 15 years of age. Children <2 years of age are uniquely susceptible to upper spinal injury because of disproportionately large heads, lax ligaments, horizontal orientation of the facets, and relatively weak cervical muscles. Limiting spinal motion can be challenging in young children and infants. A cervical collar appropriate for a child's size and anatomy is necessary. High-speed injuries, such as motor vehicle crashes and pedestrians struck by vehicles, can cause craniocervical injury (occipital condyle, C1 or C1–C2). The elasticity of the pediatric spinal ligaments exceeds that of the spinal cord. Thus, spinal alignment may appear normal, and a fracture may be absent on CT. However, the child may still have an SCI without radiographic abnormality (SCIWORA). Even in the absence of a fracture on CT, SMR is maintained if an abnormal neurologic exam is present. Evaluation by a pediatric spine expert is recommended if available. MRI may be beneficial in this scenario.

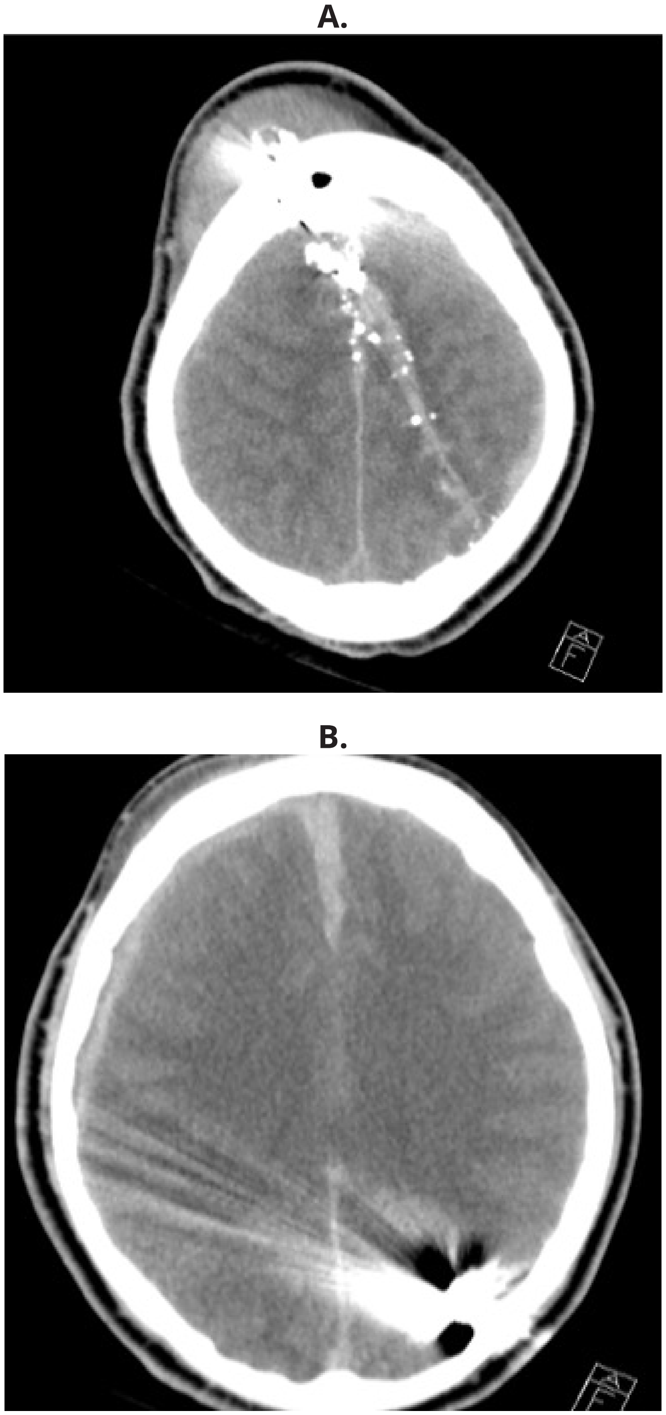
In older adults, falls are the most common cause of SCF and SCI. The aging spine is more susceptible to injury, even after seemingly minor trauma. Osteoporosis, arthritis, ankylosing spondylitis, and other conditions associated with age increase the risk of SCF and SCI. Older adults with significant baseline kyphosis may not fit in traditional cervical collars and so should be managed with padding in a position of comfort to minimize spinal motion rather than hyperextended to lay flat or conform to a cervical collar.

PENETRATING INJURIES

TRAUMATIC BRAIN INJURY

The majority of penetrating head injuries are caused by firearms. Penetrating injuries are assessed and initially managed like other major trauma. Exam includes neurologic assessment using GCS, pupillary and brainstem reflexes, motor exam, and inspection of wounds. Wounds are cleansed and covered after examination and documentation. CT imaging is indicated whenever there is a suspected penetrating injury, even if the wound is considered minor and the neurologic exam is normal. ■ **Figure 7-23** illustrates a CT scan image from a gunshot.

■ **Figure 7-23: Penetrating Brain Injury Caused by a Gunshot. A.** Projectile track with scattered bone fragments and thin rim of left subdural hematoma. **B.** Projectile lodged in the posterior parietal lobe.



Limited duration broad-spectrum antibiotic prophylaxis has been recommended based on data from military conflicts, but there remains variation in practice. High-velocity firearm injuries cause direct brain damage as the projectile passes through tissue but also create a pressure wave, which can extend damage beyond the direct path of the projectile. Wounds that pass through both hemispheres at the level of the ventricle or basal ganglia, damage the brainstem, or enter the posterior fossa have a very poor prognosis.

Surgical management is limited to patients with survivable injuries based on CT imaging and preserved brainstem reflexes. Management includes debridement of damaged brain tissue, evacuation of hematomas, repair of the dura, and closure of wounds. Damage to large cerebral vessels can result in significant blood loss and delayed pseudoaneurysms. CT angiography or catheter angiography is considered in patients with suspected vascular injury.

PENETRATING SPINAL INJURY

Penetrating spinal injuries occur less frequently than injuries caused by the two leading causes of spinal injury: motor vehicle crashes and falls. As the firearm injury public health crisis has grown, gunshot wounds are now the third-most common cause of spinal injury. Most penetrating SCIs result in a complete (ASIA A) SCI. **These injuries may be associated with significant arterial and other life-threatening injuries.** ATLS principles dictate overall management. A neurological exam and CT imaging are indicated. Many penetrating inuries are successfully managed without surgical exploration. MRI may not be possible due to retained ferrous metallic fragments. Prophylactic antibiotic administration, if performed, is of short duration except for extensively contaminated wounds. Supporting evidence of infection prevention is weak.

Surgical exploration is sometimes performed in the presence of an incomplete SCI (ASIA B or better) with progressive neurologic decline or migration of the projectile fragment. Spinal column instability is rarely present following civilian penetrating spinal injuries. As with other ballistic injury, the blast effect can cause significant damage, including spinal cord dysfunction, without passing directly through the spinal canal.

PRACTICE ENVIRONMENT CONSIDERATIONS

Neurotrauma is a critical public health issue in many countries. Inadequate emergency healthcare provision has been identified as an essential factor related to outcomes in TBI or SCI. Because access to CT scans is often lacking, alternative systems like neuro-ultrasound or near-infrared spectroscopy detectors of intracranial bleeding have been proposed but remain of unproven utility. Appropriate early resuscitation, according to ATLS principles, is the best option for TBI and SCI management, followed by prompt transfer to a neuroscience center if available.

FIELD HOSPITALS OR REMOTE LOCATIONS

A guiding principle of TBI management is prevention of secondary insults by timely resuscitation following xABCDE. After initial assessment, the patient is transferred to a medical facility where definitive care can be provided. Once the benefit of transfer has been determined, transport is not delayed to perform diagnostic radiological investigations, even head CT scan.

As mentioned earlier, outcome is improved through maintenance of adequate CBF and oxygenation. Therefore, oxygenation is optimized. Intubation and mechanical ventilation are instituted if indicated. Shock is managed, and cardiovascular status is optimized before transfer. If indicated, inotropic support is instituted before transfer. Appropriate communication with the receiving institution and preparation of all documents are performed prior to transfer.

Emergency burr-hole evacuation of an extra-axial intracranial hematoma (extradural or subdural) may be performed in a remote location where lifesaving neurosurgical intervention is not available within a reasonable timeframe. This procedure is considered in scenarios of GCS < 8 and imaging evidence of an extra-axial hematoma causing midline shift with unequal pupils. Performance of a lifesaving burr-hole procedure is preferably discussed with a neurosurgeon prior to proceeding. The clinician performing the operation must be well trained and have the appropriate equipment immediately available (e.g., a handheld drill with a specific perforator clutch bit).

CHAPTER SUMMARY

TBI and SCI are leading causes of death and disability. The Disability portion of xABCDE involves assessments for brain and spinal cord dysfunction, neurologic injury, and vertebral column instability. The GCS score and pupillary responses are utilized to grade the severity of TBI and to detect neurologic deterioration through frequent reassessment. An appropriate mechanism (e.g., penetrating injury in proximity to neurologic structures or high-force blunt trauma) prompts investigation for potential SCI and vertebral column injury. Accurate documentation and reevaluation of the sensory and motor exam is essential in management of SCI.

TBI is described by the anatomic location of injury. EDH is a collection of blood between the inner skull and dura mater. If prompt operation is performed for EDH, most patients recover without neurological deficits. The Monroe-Kellie doctrine is useful for understanding ICP.

Preservation of delivery of oxygenated blood to neurologic tissues is a main component in management of TBI and SCI. This is accomplished by maintaining blood pressure, and SpO_2 Shock is corrected expeditiously. Prompt detection of neuroworsening is critical to reducing TBI morbidity and mortality. A specialist surgeon should be consulted as soon as possible for potential interventions and treatments when TBI or SCI is present.

KEY LEARNING POINTS

- **Management of TBI and SCI is time-critical. Rapid interventions increase the probability of survival, prevent secondary damage, and reduce long-term disabilities.**
- **Hypoxia and hypotension have deleterious effects on TBI and SCI and are promptly managed. A combination of hypotension and hypoxia doubles the risk of death following TBI.**
- **CT scan is the optimal imaging investigation for both TBI and SCI.**
- **Identification of acute hematomas and rapid referral for possible neurosurgical intervention are vital to provide the optimal potential for recovery.**
- **TBI and SCI are dynamic and may worsen over time. Reassessment at regular intervals is essential.**
- **Timely recognition and management of critical neuroworsening are vital for achieving optimal outcomes.**

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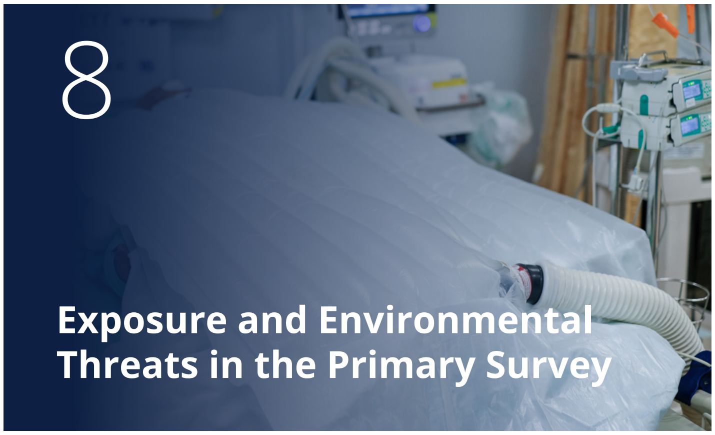
8

Exposure and Environmental Threats in the Primary Survey

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Describe how exposure and examination of the entire body in a trauma patient, using trauma-informed/humanistic care principles, assists in preventing missed injuries
2. List stabilization strategies for local and systemic environmental injuries



8

Exposure and Environmental Threats in the Primary Survey

CHAPTER STATEMENT

The “E” component of the primary survey includes the complete inspection of the patient for any previously unidentified life-threatening injuries and the prevention/correction of environmental emergencies like hypo- and hyperthermia.

INTRODUCTION/BACKGROUND

The “E” component of the primary survey has two major goals: (1) to fully expose and inspect the patient for externally visible injuries; and (2) to identify and begin treatment for any life-threatening environmental emergencies. Both systemic hypo- and hyperthermia should be identified and addressed rapidly. In particular, patients with traumatic injuries who experience hypothermia have significantly higher mortality risk. Therefore, the prevention and correction of hypothermia should be a top priority during trauma resuscitation.

PATHOPHYSIOLOGY

Environmental threats are best understood through a 2×2 grid that relates type of thermal exposure (hot versus cold) and the affected body part (local versus systemic). Hence, a systemic cold injury is termed *hypothermia*, and a systemic heat injury is termed *hyperthermia*. *Frostbite* is a local cold injury, and an acute burn is a *local hot injury* (**■ Table 8-1**).

Hypothermia is defined as a core temperature < 35°C. **Patients with traumatic injuries are at increased risk for hypothermia from exposure in the field, administration of IV fluids, hemorrhage, and in-hospital exposure.** The incidence of hypothermia in trauma patients during resuscitation has been reported to be as high as 66%. Hypothermia in trauma patients is an independent predictor of mortality.

Along with coagulopathy and acidosis, hypothermia is part of the trauma “lethal triad.” Coagulation dysfunction is seen at body temperatures < 35°C due to inhibition of the coagulation cascade, reduced platelet aggregation, and morphological changes to platelets. This makes hemorrhage control in a trauma patient significantly more challenging.

■ Table 8-1: Systemic and Local Cold versus Heat Injuries. Clinicians caring for trauma patients should be aware of the treatment of both local and systemic cold and heat injuries. Systemic hypothermia is a common problem in trauma patients with hemorrhagic shock. Although systemic hyperthermia is not as common, some emerging literature has linked heat stress syndromes to occupational traumatic injuries.

	Cold Injury	Heat Injury
Local	***Frostbite*** • Rewarm in water bath • Evaluate for possible thrombolytic therapy	***Burn*** • Cool the burn • Initiate fluid resuscitation
Systemic	***Hypothermia*** • Use tiered approach to systemic warming	***Hyperthermia*** • Apply external cooling • Use conductive cooling (if available)

Systemic hypothermia due to cold exposure can also be present in the absence of trauma. This condition must be identified and immediately addressed, as hypothermia can cause dysrhythmias and even cardiac arrest. Systemic hypothermia can be staged as I through IV, based on core body temperature. **■ Table 8-2** outlines the stages of hypothermia, their associated symptoms, and a tiered approach to correction.

Hyperthermia is defined as a core body temperature > 37.5°C caused by an extrinsic source (as opposed to fever, which is due to intrinsic cytokine activation). Body temperature > 40.5°C is considered severe hyperthermia. Evaporation is the main mechanism of body heat loss in a hot environment, but this can become insufficient if relative humidity increases. Clinically, heatstroke causes central nervous system dysfunction and multiorgan failure and carries a mortality rate of up to 63%. Rapid and effective cooling is the main determinant of a favorable outcome and should be initiated immediately upon diagnosis of hyperthermia. This will be discussed in more detail in *Chapter 9, Thermal Injuries*.

Local exposure to a source of heat or cold leads to localized skin/soft-tissue injury. The extent of injury primarily depends on the heat/cold source and the duration of contact. A major burn injury is typically defined as a burn affecting ≥ 20% of a patient’s total body surface area (TBSA). Above that 20% threshold, the injury leads to a proportionally larger systemic inflammatory response. To prevent burn shock, fluid resuscitation should begin as soon as possible; Lactated Ringers is the fluid of choice. Fluid resuscitation begins in the primary survey before TBSA is formally determined and follows an age-based algorithm (**■ Table 8-3**).

■ **Table 8-2: Stages of Hypothermia and Tiered Correction Strategies.** Hypothermia, no matter the stage, can lead to coagulation dysfunction and decreased platelet aggregation, which can in turn complicate the management of hemorrhage. Worsening hypothermia can lead to dysrhythmias and cardiac arrest.

Stage	Core Temperature	Symptoms	Interventions
I	32° — 35°C	Conscious, shivering	Warm environment and clothing, active movement, warm oral fluids
II	28° — < 32°C	Impaired consciousness, no shivering	Cardiac monitoring, cautious movements to avoid arrhythmias, full-body insulation, active external and minimally invasive rewarming techniques (chemical, electrical, or forced-air heating packs or blankets, warm IV fluids)
III	24° — < 28°C	Unconscious, vital signs are present	All the above, plus: intubation, rewarming with extracorporeal support if available
IV	< 24°C	No vital signs	All of the above plus: CPR and up to three doses of epinephrine and defibrillation, can continue if patient responds. Continue active external or internal rewarming if extracorporeal support not available

Adapted with permission of Brown DJ, Brugger H, Boyd J, Paal P. Accidental hypothermia [published correction appears in *N Engl J Med.* 2013 Jan 24;368(4):394]. N Engl J Med. 2012;367(20):1930-1938.

■ **Table 8-3: Initial Fluid Rates For Resuscitation Of Major Burn Injury.** Resuscitation of major burns should begin even before final calculation of %TBSA. If at first glance the size of the burn appears to be more than 20% TBSA, age-related resuscitation should begin and then the fluid rate adjusted as additional calculations are performed.

Initial Fluid Rate for Burn ≥20% TBSA	
≤ 5 years	125 mL of LR/hour
6–12 years	250 mL of LR/hour
≥ 13 years	500 mL of LR/hour

Frostbite is a severe and localized cold-induced injury that causes direct cell death as well as reperfusion-related injury. Early identification and evaluation are important for possible limb-saving interventions, which will be discussed in more depth in *Chapter 9, Thermal Injuries.*

ASSESSMENT

The goal of "Exposure" in the Primary Survey of a trauma patient is to examine the entire body and identify any visible external injuries that may affect the treatment plan. Penetrating wounds, bleeding from orifices such as the rectum or vagina, or evidence of soft-tissue injuries may be missed without a whole-body examination.

EXPOSURE STEPS

1. Remove all clothing, jewelry, and prehospital dressings (use shears as needed)
2. Identify external signs of injury (abrasions, contusions, bleeding, wounds, foreign bodies, burn, frostbite, etc.)
3. In patients at risk for spinal injury, log roll the patient while maintaining C-spine precautions to examine posterior aspect of the patient for signs of injury
4. To respect patient privacy and reduce hypothermia, cover the patient as much as possible during the examination and completely after the exam

The exposure and subsequent steps to cover the patient are a great opportunity to provide the best humanistic care possible to the patient. The clinician should acknowledge any visible injury and its potential impact and should communicate with the patient and family that they seek a collaborative strategy based on mutual respect to ensure optimal care.

INTERVENTIONS/TREATMENTS

The general strategy for initial stabilization of each environmental injury is summarized in ■ **Table 8-1**. A tiered approach is necessary to aggressively correct hypothermia (■ **Table 8-2**). Severe hyperthermia (temperature > 40.5°C) should be addressed with rapid external cooling. Cold water immersion is the most effective cooling technique but is not always practical or available. Application of ice packs at vascular junctional points (neck, axilla, groin) and evaporative cooling (through continuous fanning) are the next best options. If available, modern conductive devices such as intravascular catheters are very effective in facilitating rapid cooling.

Patients with an apparent large burn injury (≥ 20% TBSA) should be started immediately on warm fluid resuscitation before doing a formal calculation of injury TBSA and obtaining the patient's weight (■ **Table 8-3**). Although immediate resuscitation of isolated burn injuries is critical, clinicians must also realize that, as in other clinical situations, crystalloid boluses quickly exit the intravascular space and promote interstitial edema. The initial resuscitation should begin at the age-specific rates noted in ■ **Table 8-3**; boluses should be avoided unless the patient is hypotensive. For major burns, the benefit of cooling the burned areas may be outweighed by the risk of incurring systemic hypothermia, and therefore surface cooling should be done with caution. **Patients who present with frostbite should undergo immediate rewarming in a 40°C circulating water bath and be evaluated for possible thrombolytic therapy (in discussion with regional referral centers) to maximize digit and limb salvage.**

Resuscitating patients with IV crystalloid can have several disadvantages that clinicians should consider. In patients with significant hemorrhage, crystalloid infusion has been associated with coagulation dysfunction and may contribute to existing hypothermia as well as other complications. There are certain settings in which crystalloid infusion is appropriate, such as in patients with isolated neurogenic shock or isolated major burn injuries. In these circumstances, clinicians should still administer these fluids warmed and should monitor patient core temperature closely for signs of hypothermia.

CHAPTER SUMMARY

The "E" in the Primary Survey algorithm includes both exposure of the patient to perform a complete examination and identification of any visible injuries. As much as possible during and at the completion of the exam, the patient should be covered, both to maintain privacy and to assist in preventing hypothermia, a common condition seen in trauma patients. Local heat and cold injuries, such as thermal burns and frostbite, should be treated according to established protocols (*see Chapter 9, Thermal Injuries*). Hyperthermia is not usually seen in trauma patients, although some literature suggests a link between heat stress syndromes and occupational traumatic injuries. Hypothermia is more commonly seen in trauma patients; if present, it should be aggressively treated. Any stage of hypothermia can contribute to coagulation dysfunction and complicate resuscitation. Hypothermia is an independent predictor of mortality in trauma patients.

KEY LEARNING POINTS

- **The "E" component of the primary survey has two major goals:**
  - **1) Full-body exposure to ensure the identification of external signs of injury**
  - **2) Identification and immediate treatment of life-threatening environmental injury**
- **Humanistic, Trauma-Informed Care mandates that patients' dignity and privacy be protected during the examination. If possible, parts of the body that are not being examined should be covered. Once the examination is completed, the patient should be completely covered and care taken to prevent hypothermia.**
- **Patients with traumatic injuries are at increased risk of hypothermia from exposure in the prehospital environment, hemorrhage, administration of IV fluids, and inhospital exposure.**
- **For major burns (≥ 20% TBSA), initiate fluid resuscitation using Lactated Ringer's solution based on age cutoffs.**
- **For frostbite injury, rewarm the affected extremity by immersion and evaluate for possible thrombolytic therapy.**

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9

Thermal Injuries

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, you will be able to do the following:

1. Explain how the pathophysiology of burn injury guides patient management
2. Estimate the size and depth of a burn injury and apply to initial treatment
3. Develop a plan for initial management that includes resuscitation of severe burns
4. Describe common mechanisms of burn injuries and explain the impact of specific mechanisms on patient management
5. Recognize and manage life-threatening systemic hyperthermia and hypothermia
6. Recognize and initiate treatment for localized cold injury (frostbite)
7. Identify and manage common pitfalls in burn and environmental injury management

9

Thermal Injuries

CHAPTER STATEMENT

Like other types of trauma, thermal injuries are evaluated and treated within the ATLS® framework. Accurate assessment of burn or cold injury extent and depth, along with appropriate resuscitation, can prevent both short- and long-term complications. Criteria for consultation with specialized burn centers are well established and should be followed.

INTRODUCTION

Thermal injuries are a major cause of morbidity and mortality. However, adherence to the basic principles of ATLS and the timely application of simple emergency measures can minimize complications. The impact of burn injury is directly linked to the extent of the inflammatory response, which develops gradually over the hours immediately following the injury. Without initiating proper treatment, burn shock develops, leading to organ failure and death. Therefore, stabilization of severe burns requires prompt treatment with frequent reassessments and adjustments.

STOP THE BURNING PROCESS

Similar to mitigating external hemorrhage with Stop the Bleed® strategies, **skin burns need to be immediately dealt with by stopping the injury source.** In the field, this often starts with extinguishing a fire and removing people from the heat source causing flame burns or scalds. For adherent materials like tar, ensure that the burns have been cooled to the touch. Decontamination from chemical agent exposure is an early priority, with care to protect first responders from contamination. Brush any dry chemical powders from the wound and irrigate with copious warm irrigation (or use a decontamination shower).

Cool burn wounds with room-temperature running tap water for 20 minutes. Cooling can be effective if initiated within 3 hours following injury. Care must be taken to avoid hypothermia (especially in larger burns). Do not use ice. Once the burning process has been stopped, quickly cover the patient with warm, clean, dry linens to prevent hypothermia.

BURN CARE PRIORITIES WITHIN THE PRIMARY SURVEY

AIRWAY

Inhalation injury is present in 2%–14% of patients who are admitted to burn centers and may occur without cutaneous injury. There are three major categories of inhalation injury: supraglottic, subglottic, and systemic poisoning (see Breathing).

Early evaluation to determine the need for endotracheal intubation is essential. A history of exposure to smoke or chemical vapors in an enclosed space should increase concern for airway injury. Patients presenting with signs of respiratory distress should be intubated. Factors that increase the risk for upper airway obstruction include larger burn size and depth, deep burns to the head and face, and burns inside the mouth (**■ Figure 9-1**). Carboxyhemoglobin level (COHb) should be measured as an adjunct; a level > 10% often indicates significant exposure. Children with burn injuries are at higher risk for airway obstruction than adults due to their smaller airways. **Circumferential burns to the neck and chest may also compromise the airway and gas exchange.**

The clinical manifestations of subglottic inhalation injury may be subtle and progressively appear within the first 12–24 hours. When in doubt, examine the patient's oropharynx for signs of inflammation, mucosal injury, soot in the pharynx, and edema, taking care not to injure the area further.

The following situations should prompt immediate intubation:

- Signs of airway obstruction (hoarseness, stridor, accessory respiratory muscle use, sternal retraction)
- Signs of respiratory compromise (inability to clear secretions, respiratory fatigue, poor oxygenation or ventilation)
- Decreased level of consciousness where airway protective reflexes are impaired

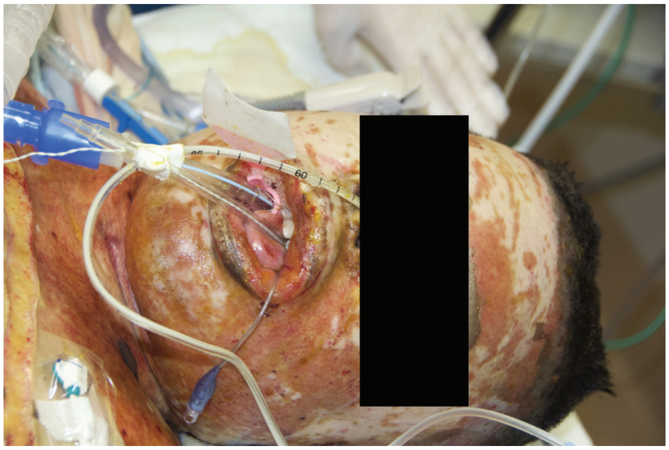
Other situations where airway intervention may be indicated include the following:

- Very large total body surface area (TBSA) flame burns (typically > 40%–50%)
- Extensive and deep facial burns
- Burns inside the mouth

It is important to place an appropriately sized endotracheal tube (ETT) for age and sex. **The first intubation attempt should be the definitive one, performed by the most experienced clinician available.** Placing a tube that is too small will make ventilation, clearing of secretions, and bronchoscopy difficult or impossible. Having to exchange an ETT in a patient with developing edema is dangerous. Standard adult bronchoscopes will fit inside a 7-mm interior-diameter ETT, and most pediatric bronchoscopes will fit in a 4.5-mm interior-diameter ETT.

Realize that airway obstruction in a patient with a burn injury may not be present immediately; frequent reevaluation of the patient for changes in airway status is crucial.

■ Figure 9-1: Airway Compromise Associated with Acute Thermal Burn. Patients with acute thermal burns to the face or mouth may require a secure airway, either due to direct injury, inhalation injury, or progressive edema. Any patient with significant oral/facial burns or signs/symptoms of inhalation injury should be considered for endotracheal intubation. All burn patients should be monitored closely, as edema may not be immediately apparent and may only manifest as resuscitation continues.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BREATHING

Breathing concerns arise from three general causes: hypoxia, carbon monoxide (CO) poisoning, and smoke inhalation injury. As a baseline for evaluating the pulmonary status of a patient with smoke inhalation injury, clinicians should obtain a chest x-ray and arterial blood gas (ABG) determination. These values may deteriorate over time; normal values on admission do not exclude inhalation injury. Smoke inhalation can cause airway compromise from either chemical or particulate injury. Smoke inhalation injury is treated with supportive care.

Hypoxia may be related to inhalation injury, inadequate ventilation due to circumferential chest burns, or thoracic trauma unrelated to the thermal injury. Administer 100% oxygen to all burn patients during the primary survey.

Always assume CO exposure in patients who were burned in enclosed areas. The diagnosis of CO poisoning is made primarily from a history of exposure and direct measurement of COHb. Patients with COHb levels <20% may have no physical symptoms. Higher COHb levels can result in the following:

- Headache and nausea (20%–30%)
- Confusion (30%–40%)
- Coma (40%–60%)
- Death (> 60%)

Hemoglobin has more than 200 times greater affinity for CO than for oxygen. Thus, CO displaces oxygen from the hemoglobin molecule and shifts the oxyhemoglobin dissociation curve to the left. The elimination half-life of CO is approximately 4 hours when the patient is breathing room air but can be reduced to 40-50 minutes by breathing 100% oxygen.

An ABG assay should be obtained as a baseline for evaluating pulmonary status if the patient has been involved in a closed-space fire. COHb levels should be obtained, and 100% oxygen should be administered. If COHb level is not known, presumptive treatment with 100% oxygen for 4 to 6 hours is reasonable. In a patient with CO poisoning, a standard pulse oximeter may read 98%–100% saturation and not reflect true oxygen saturation, which must be obtained from the ABG. Special co-oximetry equipment may be used, but this is not widely available.

Cyanide inhalation from the products of combustion is possible with burns occurring in confined spaces, in which case the clinician should consult with a burn or poison control center. Signs of potential cyanide toxicity are persistent hypotension and profound metabolic acidosis that are unexplained by other causes. In the prehospital and emergency department setting, candidates for presumptive treatment of cyanide toxicity have the following combination: CPR in the field, loss of consciousness, GCS < 10, lactate > 10, and COHb > 10. Antidote treatment consists of the administration of hydroxycobalamin. Otherwise, the definitive care center can selectively administer hydroxycobalamin to patients who exhibit symptoms of cyanide toxicity during the resuscitation phase.

There is no role for hyperbaric oxygen therapy in the primary resuscitation of a patient with critical burn injury.

CIRCULATION

Acute burns do not cause life-threatening hemorrhage. Instead, fluid loss is progressive, and proactive burn resuscitation should be initiated immediately for patients with large burn injuries. If peripheral IV insertion is not rapidly successful, consider intraosseous access to start resuscitation. Isotonic fluid resuscitation should be administered in the prehospital setting and continued in the primary survey, based on the patient's age, as follows:

- ≤ 5 years old: 125 mL lactated Ringer's (LR) per hour
- 6–12 years old: 250 mL LR per hour
- ≥ 13 years old: 500 mL LR per hour

If fluids were not started in the prehospital phase, immediately initiate the age-based fluid rate shown above while performing the primary survey. Delay only promotes burn shock. On the other hand, bolus fluid administration is discouraged unless the patient is hypotensive or has other signs of severe hypovolemia. Bolus fluids promote "third spacing" rather than simply increasing intravascular volume. Peripheral pulses should be evaluated in all extremities during the primary survey.

DISABILITY

As with all trauma patients, a neurologic assessment of pupils, GCS, and ability to move all extremities should be obtained. Mental status changes can aid in the early diagnosis of hypoxemia or shock.

EXPOSURE

A common life-threatening finding during the primary exam is hypothermia. Limb-threatening cold injury should also be rapidly assessed. Please refer to *Chapter 8, Exposure and Environmental Threats in the Primary Survey*, for additional reading on environmental threats.

BURN PRIORITIES IN THE SECONDARY SURVEY

The secondary survey consists of gathering additional history, performing a head-to-toe examination, and, for burn patients, calculating the TBSA burn size. Adjusted fluids are then calculated based on TBSA.

HISTORY

At minimum, the AMPLE history should be obtained, as in all patients. For patients with burns, particular attention should be paid to the mechanism of burn, duration of contact, circumstances of burn, and time of injury. Patients can sustain associated injuries while attempting to escape a fire, and explosions can result in factures and internal injuries (e.g., central nervous system, myocardial, pulmonary, and abdominal injuries). Be aware that some burn injuries may be intentional. Individuals may attempt suicide through self-immolation, and both children and vulnerable adults may experience abuse. Match the patient history to the burn pattern; if the account of the injury is suspicious, consider the possibility of an intentional injury.

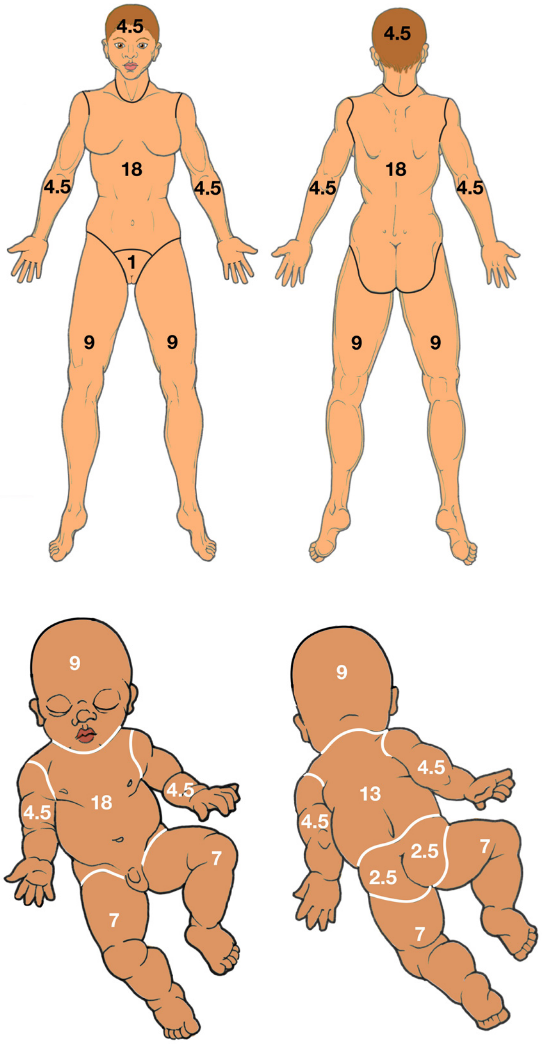
BODY SURFACE AREA AND DEPTH

The **rule of nines** is a practical guide for determining the extent of a burn using calculations based on areas of partial- and full-thickness burns (**■ Figure 9-2**). The adult body configuration is divided into anatomic regions that represent multiples of 9%. Body surface area distribution differs considerably for children, because a young child's head represents a larger proportion of their surface area and their lower extremities represent a smaller proportion than an adult's. The patient's hand surface (including the palm and fingers held together) represents approximately 1% of the patient's body surface. Other methods such as Lund-Browder charts or apps with body surface area charts are also acceptable.

Documenting the location of the burn is best done using a patient diagram indicating location and depth for each affected area. Soot and unruptured (or partially ruptured) blisters can obscure a view of the wound base. In individuals with very fair or darker skin tones, it may be difficult to assess injury depth on visual inspection alone. **To improve the ability to assess the size and depth of burn injury, the clinician should interact with the patient's skin and, if necessary, wipe away some blisters to get an adequate assessment of size and depth.**

The depth of burn is also important in evaluating the severity of a burn and planning for wound care. Tips to avoid errors in TBSA estimates are listed in **■ Box 9-1**.

■ Figure 9-2: "Rule of Nines" for Burn Extent Calculation in Adult and Pediatric Patients. The "Rule of Nines" is one method to estimate the extent of burn in both adult and pediatric patients; it is based on the relative Total Body Surface Area (TBSA) of different anatomic areas of the body. Note that the head on the child accounts for a relatively larger TBSA than in the adult.



■ Box 9-1: Tips to Prevent Over- or Underestimating Burn Size.

Tips to Prevent Over- or Underestimating Burn Size

- Do not include superficial (first-degee) burns in size estimation.
- Use the rule of nines, recognizing that children have proportionately larger heads than adults.
- For irregular or oddly sized burns, use the patient's palm and fingers to approximate 1% body surface area (BSA).
- For larger burns it may be easier to count the unburned areas and subtract from 100.
- Remember to log roll patient to assess their posterior side.

Superficial (first-degree) burns (e.g., sunburn) are characterized by erythema and pain, and they do not blister. These burns are not life-threatening and do not result in a significant inflammatory response. Resuscitation is not required, and first-degree burned areas should not be included in TBSA calculation. (■ **Figure 9-3B**).

Partial-thickness (second-degree) burns (■ **Figure 9-3C**) are characterized as either superficial partial-thickness or deep partial-thickness. Superficial partial-thickness burns are moist, painful, and homogenously pink; they blanch to touch and may have intact blisters. Deep partial-thickness burns are drier, less painful, red or mottled in appearance, and do not blanch to touch.

Full-thickness (third-degree) burns usually appear leathery (■ **Figure 9-3D**). The skin may appear deep red, brown, or waxy white. The surface is generally dry, does not blanch, and is painless to light touch or pinprick.

CALCULATE THE ADJUSTED FLUID RATE

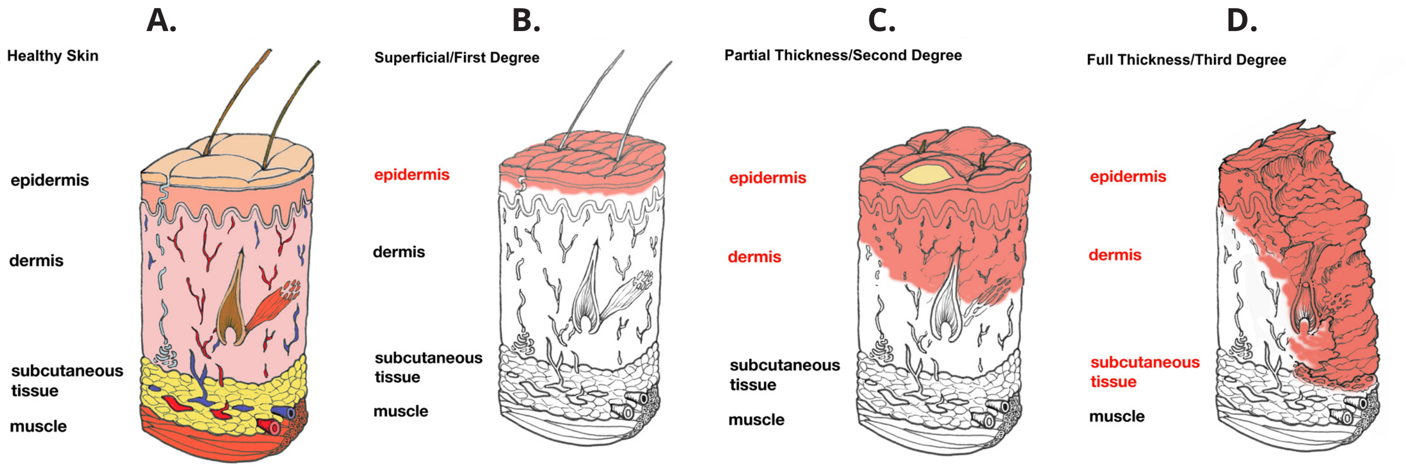
In contrast to resuscitation for other types of trauma, in which shock is typically due to blood loss, burn resuscitation is required to replace the ongoing, progressive losses from capillary leak proportional to the burn TBSA. Clinicians should provide burn resuscitation fluids for partial- and full-thickness burns ≥20% TBSA based on the chart in ■ **Table 9-1**.

Adjusted fluids should be administered as warmed isotonic crystalloid, preferably LR solution. Insert an indwelling urinary catheter in all patients receiving formal burn resuscitation. Fluids should be adjusted on an hourly basis to maintain a goal urine output of 30–50 mL/hr in adults (generally equivalent to 0.5 mL/kg/hr). For pediatric patients (age < 14 years), the goal is 1 mL/kg/hr. For patients with urine output below the target rate, the hourly fluid rate for burn resuscitation should be increased by 10%–30%. When patients are producing urine output above goal, the hourly rate should be reduced by 10%–30%. Beware that osmotic diuresis (e.g., glycosuria, alcohol, or use of mannitol) lowers the utility of urine output as a marker of effective perfusion.

■ **Table 9-1: Age-Based Adjusted Hourly Fluid Rates and Urine Output Goals for Thermal/Chemical and Electrical Burns.** Once the extent of the burn is calculated (%TBSA), adjusted fluid rates can be calculated using that information and the patient's age and their weight in kilograms. Electrical injury calculations apply to all ages. Fluids can then be further adjusted to meet age-based urine output goals.

Category of Burn	Age and Weight	Adjusted Hourly Fluid Rate (ml/hr)	Urine Output Goal
Thermal or Chemical Burn	Adults and Older Children ≥13 years old	$\frac{\text{2 ml LR x kg x \% TBSA}}{16}$	0.5 ml/kg/hr (30–50 ml/hr)
	Children <13 years old	$\frac{\text{3 ml LR x kg x \% TBSA}}{16}$	1 ml/kg/hr
	Infants and young children ≤ 30 kg	$\frac{\text{3 ml LR x kg x \% TBSA}}{16}$ Plus D5LR at maintenance rate	1 ml/kg/hr
Electrical Injury	All ages	$\frac{\text{4 ml LR x kg x \% TBSA}}{16}$ Children <13 years old require D5LR at maintenance rate	1–1.5 ml/kg/hr until urine is clear of pigment

■ **Figure 9-3: Determining Burn Depth. A.** Healthy Skin **B.** Superficial/First degree **C.** Partial thickness/Second degree **D.** Full thickness/Third degree. The figures illustrate the depth of burn.



EXAMPLE OF ADJUSTED FLUID CALCULATION

A 100 kg man with 80% TBSA burns has an estimated need for 2 × 80 × 100 = 16,000 mL in 24 hours of crystalloid resuscitation. The total fluid volume estimate should be divided by 16 to obtain the adjusted fluid rate. Though he should have received 500 ml/hour in the prehospital phase (before injury TBSA could be accurately estimated), the fluid rate should be increased to 1000 mL/hr during the secondary survey. In subsequent hours, the fluid rate should be decreased as able, based on his urine output response. Traditional formulas have caused some clinicians to adhere too rigidly to administering the first half of the total fluid volume estimate in the first 8 hours and the second half in the following 16 hours. It is important to emphasize that traditional formulas are primarily useful to calculate adjusted fluid rates once burn TBSA is known.

One consequence of fluid resuscitation is the development of edema, which takes time to develop. In anticipation of this, longer IV catheters should be used if possible, and endotracheal tubes should be checked frequently to ensure no change in position.

The key principle is that fluid resuscitation must be adjusted based on the patient response. The calculation does not prescribe fluid rate for the hours subsequent to the initial assessment. The clinician should base the reduction in IV fluid rate on urine output and titrate to a lower rate if urine output is adequate.

During the first 24–48 hours of burn resuscitation, fluid boluses should generally be avoided unless the patient is hypotensive. Hypotension indicates that the patient is in shock and that resuscitation has been inadequate. In such a case, a bolus is appropriate and the hourly fluid rate should be increased. Low urine output by itself is best treated with gradual titration of the fluid rate.

Very small children (<30 kg) should receive LR containing 5% dextrose at maintenance rate in addition to the burn resuscitation fluid. This fluid is not titrated and is meant to ensure a minimum maintenance and prevent hypoglycemia. Remove the dextrose component in case of hyperglycemia, and continue to monitor glucose levels.

Clinicians should take care to avoid under- or over-resuscitation of burn patients. Fluids should be titrated to the patient's physiologic response, adjusting the fluid rate up or down based on urine output. **Boluses should be avoided unless the patient is hypotensive**. Clinicians should also recognize factors that affect the volume of resuscitation and urine output, such as inhalation injury, renal insufficiency, diuretics, and alcohol.

PERIPHERAL CIRCULATION IN CIRCUMFERENTIAL EXTREMITY BURNS

To maintain peripheral circulation in patients with circumferential extremity burns, the clinician should remove all jewelry or constricting clothing material, elevate limbs, and frequently assess the neurovascular status of affected limbs.

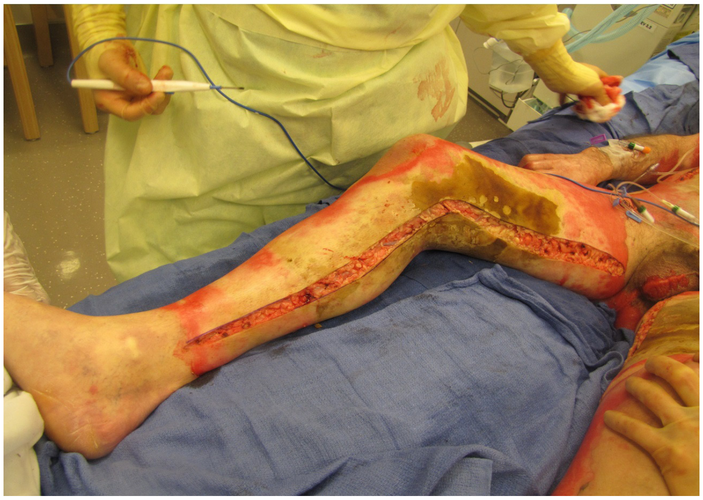
Compartment syndrome results from pressure inside an inelastic body space increasing to the point that it interferes with perfusion to the structures within that space. In burns, this condition results from the combination of decreased skin elasticity in deep burns and increased edema in soft tissue. Clinicians must be aware of the signs and symptoms of compartment syndrome:

- Pain greater than expected and out of proportion to the stimulus or injury
- Pain on passive stretch of the affected muscle
- Tense swelling of the affected compartment
- Paresthesias or altered sensation distal to the affected compartment
- Loss of pulses (a late finding)

Once the pulse is gone, it may be too late to save the muscle, so do not wait for loss of pulses to act. If compartment syndrome is suspected in a limb with eschar, escharotomy is indicated to release the burned skin (■ **Figure 9-4**). This procedure should be done in consultation with a burn center.

Compartment syndromes may also occur with circumferential chest and abdominal burns and be diagnosed by increased peak inspiratory and abdominal pressure measurements. Chest and abdominal escharotomies, performed along the anterior axillary lines with a cross-incision at the junction of the thorax and abdomen, usually relieve the problem. For patients with high-voltage electrical injury, compartment syndrome may develop within the muscle fascia compartment. In such cases, muscle compartment fasciotomy is necessary.

■ **Figure 9-4: Extremity Escharotomy.** In patients with circumferential extremity full-thickness burns with eschar, an escharotomy can be performed to treat a suspected compartment syndrome. Insicions are usually made on the medial and lateral aspects of the limb, crossing joints if necessary, to release the eschar. Similar techniques can be employed for circumferential wounds with eschar in the thorax, abdomen, and neck.



PAIN AND ANXIETY MANAGEMENT

Severely burned patients may be restless and anxious from hypoxemia or hypovolemia rather than pain. Consequently, manage hypoxemia and inadequate fluid resuscitation first. Opioid analgesics and sedatives should be administered in small, repeated doses, preferably by IV. Reassess frequently, and remember that anxiety can contribute to the patient's pain experience. Remember that simply covering the wound will decrease pain.

WOUND CARE

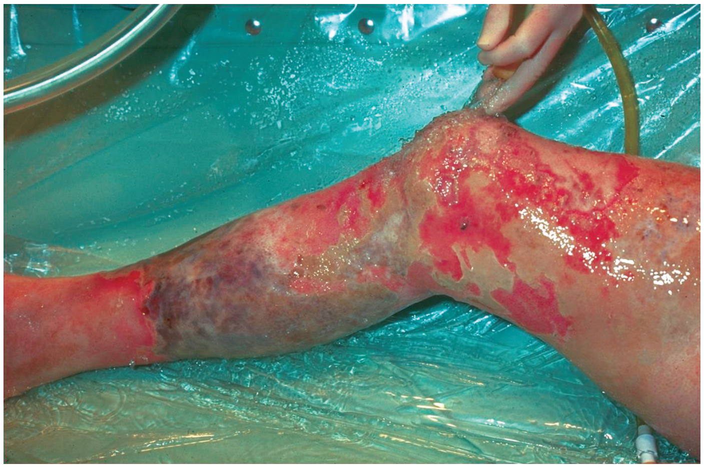
For large burns, particularly when patients are intubated and sedated, covering the burns with clean, dry linens is adequate while planning transfer to a facility that can provide definitive care. For smaller burns (< 20%), it may be necessary to wipe away gross contamination or soot that interferes with TBSA assessment using a moist wash cloth. Partial-thickness burns are painful when air currents pass over the burned surface and are often weeping and wet, which will stick to linens and dressings.

It is not necessary to break blisters or apply an antiseptic agent, as this care will be provided at the referral center. For smaller, shallower open burn wounds (i.e., when the blistered, dead skin is already off), applying a nonstick dressing (or even plastic wrap) keeps the open wound clean and protected during transfer. A fresh burn is a clean area that must be protected from contamination. Do not administer systemic antibiotics prophylactically for the burn wound. Tetanus status should be determined and treated as indicated. Initial wound care is summarized in ■ **Box 9-2**.

CHEMICAL BURNS

Chemical injury can result from exposure to acids, alkalis, and petroleum products. Chemical burns are influenced by the duration of contact, concentration of the chemical, and amount of the agent. **Only the duration of contact can be modified by the clinician, and rapid removal of the chemical is essential**. If dry powder is present on the skin, brush it away before irrigating with water. Otherwise, immediately flush away the chemical with large amounts of warm water for at least 20 to 30 minutes, using a shower or hose (■ **Figure 9-5**). Alkali burns require longer irrigation. Check the affected skin pH with pH paper to determine the effectiveness of irrigation. **Neutralizing agents offer no advantage over water lavage**, because reaction with the neutralizing agent can itself produce heat and cause further tissue damage.

■ **Figure 9-5: Chemical Burn.** Stopping the burning process for chemical burns can involve brushing away dry particles along with irrigation of the affected area with water (as seen in Figure). Irrigation times of 30 minutes or longer are usually necessary. Information about the nature of the chemical is helpful if it can be obtained.



For eye irrigation, a small-caliber cannula can be fixed in the palpebral sulcus. In the event of hydrofluoric acid burns, topical calcium should be applied immediately. Once initial decontamination has been started, clinicians should then investigate more thoroughly the type of exposure. With any chemical exposure it is important to ascertain the nature of the chemical and, if possible, obtain a copy of the relevant material safety data sheet. Follow first-aid procedures on the material safety data sheet and contact a poison control center to address systemic toxicity threats as necessary.

■ **Box 9-2: Initial Wound Care Recommendations.**

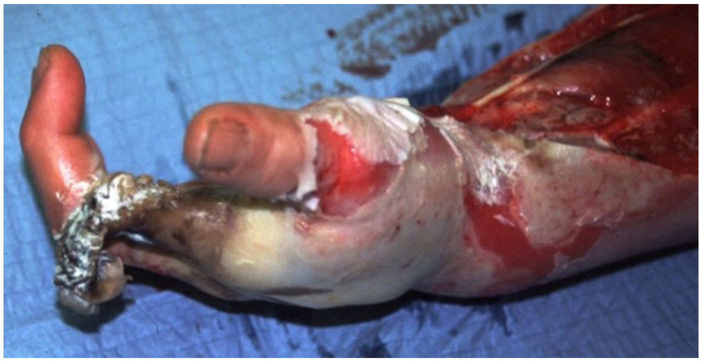
Initial Wound Care Recommendations

Recommendation	Rationale
Use plastic wrap or nonadherent dressings for transfer	*Dry dressings adhere to small, shallow burns*
Use small, repeated IV opioid doses for analgesia	*Provides more immediate pain control that can be titrated to response*
Prevent superficial wounds from drying	*Drying can increase pain*
Frequently reassess dressings for tightness and constriction Remove constricting rings and other jewelry and clothing early	*Patients can develop deep-tissue injury from constricting dressings and ties, especially as edema develops*
Be alert for deep circumferential burns Monitor pulses and elevate the affected extremities in these cases	*Remember that edema takes time to develop* *Recognize that burned skin with eschar cannot stretch, and patients can develop deep-tissue injury from constricting burn eschar. Deep circumferential burns may require escharotomy*

ELECTRICAL INJURY

Electrical injury results from electrical current transmitted through the body. These injuries are divided into high voltage (≥ 1,000 V) and low voltage (< 1,000 V). The body can serve as an incidental conductor of electrical energy, and the heat generated from tissue resistance results in additional thermal injury. Differential heat generation between superficial and deep tissues allows relatively normal overlying skin to coexist with deep-muscle necrosis (■ **Figure 9-6**). Severe electrical injuries usually result in acute contracture of the affected extremity. A clenched hand with a small electrical contact wound should alert the clinician that a deep soft-tissue injury is likely and fasciotomy is necessary.

■ **Figure 9-6: Electrical Burn.** This figure demonstrates an injury with deep-tissue necrosis coexisting with areas of "normal" skin. A hallmark of electrical injury is a relatively small visible wound that hides significant tissue injury. Clinicians must be vigilant in monitoring for cardiac, renal, and other complications.



All patients should undergo ECG as an adjunct to physical assessment. Patients with no loss of consciousness, a minimal wound burden, and a normal ECG may be safely discharged after low-voltage injury. Prolonged monitoring is reserved for patients with severe burn (deep and/or extensive), loss of consciousness, exposure to high voltage (≥1,000 V), or cardiac rhythm abnormalities on initial ECG. Any patient with electrical injury who develops signs of acute kidney injury/failure should have a 12-lead ECG and continuous monitoring.

Electrical injuries are often associated with falls and frequently occur at work. Forced contraction of muscles may cause skeletal and muscular damage. Patients with high-voltage injury should be assessed for mechanical trauma including spinal column and spinal cord injuries. **Clinicians should also remember that with electrical burns, muscle injury can occur with few outward signs of injury.** Serially assess the patient for compartment syndrome, recognizing that electrical burns may necessitate fasciotomies.

Rhabdomyolysis from electricity traveling through muscle results in myoglobin release, which can cause acute kidney injury/renal failure. If the patient's urine is dark red, assume that hemochromogens are in the urine; test for myoglobin to confirm if possible. Resuscitation for electrical burn injury should start based on the following calculation: 4 mL/kg/%TBSA, as visible surface injury often grossly underestimates the extent of deeper injuries. As in thermal trauma, this value should be divided by 16 to obtain the hourly fluid rate for the secondary survey. If red pigmented urine is present, the urine output goals are 100 mL/hr in adults and 2 mL/kg/hr in children. Once the urine is clear of red pigmentation, fluids can be titrated down to standard urine output targets.

BURN PATTERNS IN VULNERABLE INDIVIDUALS

It is important for clinicians to be aware that intentional burn injury can occur in both children and vulnerable adults. Contact patterns with clear edges should arouse suspicion; they may reflect a hot object (e.g., an iron) being held against the patient. Scald burns on the soles of a child's feet may suggest that the child was placed into hot water versus having hot water fall on them. Sparing of the buttocks is another classic sign, as contact with a bathtub or basin surface can protect these areas during forced immersion. Bathing burns in older or dependent adults are also concerning for abuse or neglect. Old burn injuries in the setting of a new traumatic injury (such as a fracture) or burn wounds of different ages should also raise suspicion for abuse. Above all, the mechanism and pattern of injury should match the history of the injury.

PATIENT TRANSFER

Guidelines for consultation and transfer should take into consideration local burn preparedness and existing regional capabilities. For instance, the **American Burn Association has adopted the following guidelines for patient consultation and transfer to regional burn centers in the US and Canada** (■ **Table 9-2**).

Transfer of any patient must be coordinated with the referral center staff. All pertinent information regarding test results, vital signs, fluids administered, and urinary output should be documented and sent with the patient. Documentation of the burn wound size should be included in the transfer documents. Airway status should be reevaluated and confirmed prior to transfer; if the patient is to be transferred unintubated, a discussion with the transport personnel and receiving facility should be had to ensure that the patient's airway can be managed during transport.

COLD INJURY

There are two types of cold injury: frostbite and nonfreezing injury. The severity of cold injury depends on temperature, duration of exposure, environmental conditions, amount of protective clothing, and the patient's general state of health. Lower temperatures, immobilization, prolonged exposure, moisture, the presence of peripheral vascular disease, and open wounds all increase the severity of cold injury.

■ **Table 9-2: American Burn Association (ABA) Guidelines for Consultation and Transfer.** Developed for use in the United States and Canada, the ABA Guidelines can be useful in any region for developing a framework for when consultation and transfer of burn patients to specialty care should be considered. Any protocols should take into account regional capabilities.

Transfer Guidelines by the American Burn Association

Injury	Immediate Consultation with Consideration for Transfer	Consultation Recommendation
Thermal Burns	Full-thickness burns Partial thickness ≥10% TBSA* Any deep-partial or full thickness burns involving the face, hands, genitalia, feet, perineum, or over any joints Patients with comorbidities Patients with concomitant traumatic injuries Poorly controlled pain	Partial thickness burns <10% TBSA* All potentially deep burns of any size
Inhalation Injury	All patients with suspected inhalation injury	Patients with signs of potential inhalation such as facial flash burns, singed facial hairs, or smoke exposure
Pediatrics (≤ 14 years or < 30 kg)	All pediatric burns may benefit from burn center referral due to pain, dressing change needs, rehabilitation, patient/caregiver needs, or non-accidental trauma	
Chemical Injuries	All chemical injuries	
Electrical Injuries	All high voltage (≥1,000V) electrical injuries Lightning injury	Low voltage (<1,000V) electrical injuries should receive consultation and consideration for follow-up in a burn center to screen for delayed symptom onset and vision problems

***Total body surface area**

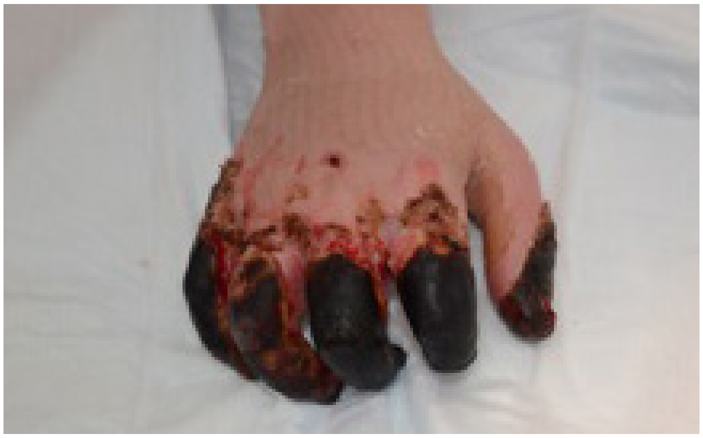
FROSTBITE

Frostbite occurs when tissues freeze; ice crystal formation causes cell membrane injury, microvascular occlusion, and subsequent tissue anoxia (■ **Figure 9-7**). Tissue damage can also result from reperfusion injury after rewarming. Frostbite is classified as follows:

- First-degree frostbite: Hyperemia and edema are present without skin necrosis
- Second-degree frostbite: Large, clear vesicle formation accompanies the hyperemia and edema with partial-thickness skin necrosis
- Third-degree frostbite: Full-thickness and subcutaneous tissue necrosis occurs, commonly with hemorrhagic vesicle formation
- Fourth-degree frostbite: Full-thickness skin necrosis occurs, including muscle and bone progressing to necrosis

Typically, the affected body part is initially cold, hard, white, and numb. Initial treatment regimen applies to all degrees of frostbite, and the classification is often not prognostically accurate.

■ **Figure 9-7: Frostbite with Tissue Damage and Loss.** As with thermal burns, frostbite is staged from first to fourth degree; higher levels of injury are associated with significant tissue damage and complications. Immediate rewarming is critical to decreasing the duration of tissue freezing.



Patients with third-degree frostbite can develop severe swelling of the extremity with rewarming; clinicians should anticipate the potential for reperfusion injury. Prevention of further tissue injury can be aided by elevating the extremity and keeping the affected area free of constricting wraps. Muscle compartments must be frequently monitored. **Clinicians should also remember that demarcation between live and dead tissue may take days to weeks to develop.** Monitoring the site for infection is also critical.

NONFREEZING INJURY

Nonfreezing injury is due to microvascular endothelial damage, stasis, and vascular occlusion. "Trench foot" or "cold immersion foot" (or hand) describes a nonfreezing injury of the hands or feet, typically seen in soldiers, sailors, fishermen, and those who are unhoused. The skin injury results from repeated and prolonged exposure to wet conditions and temperatures just above freezing (1.6°C–10°C, or 35°C–50°F). Although the entire foot can appear black, deep-tissue destruction may not be present. Alternating arterial vasospasm and vasodilation occur, with the affected tissue first cold and numb, then progressing to hyperemia in 24 to 48 hours. With hyperemia comes intense, painful burning and dysesthesia, as well as edema, blistering, redness, ecchymosis, and ulcerations. Complications of local infection, cellulitis, lymphangitis, and gangrene can occur. During follow-up care, patients should be informed that proper attention to foot hygiene can prevent many of these complications.

MANAGEMENT OF FROSTBITE AND NONFREEZING COLD INJURIES

Treatment should begin immediately to decrease the duration of tissue freezing. Do not attempt rewarming if there is a risk of refreezing. Replace constricting, damp clothing with warm blankets. Immerse the injured part in recirculating water at a constant 40°C (104°F) until pink color and perfusion return (usually within 20 to 30 minutes). This treatment is best accomplished in an inpatient setting in a large tank, such as a whirlpool tank, or by placing the injured limb into a bucket with warm, running water. Excessive dry heat can cause a burn injury, as the limb is usually insensate. Do not rub or massage the area. Rewarming can be extremely painful, and adequate analgesics are essential. Reperfusion of large areas can result in reperfusion syndrome, with acidosis, hyperkalemia, and local swelling. Therefore, it is important to monitor the patient's cardiac status and peripheral perfusion during rewarming.

Referring hospitals and clinicians should discuss with the regional referral unit for the use of thrombolytic therapy in acute frostbite. **Thrombolytics may be considered in patients presenting within 24 hours of injury.** Thrombolytic therapy is most effective when developed as part of a protocol of care rather than as an ad hoc strategy. For patients with tissue cyanosis, CT angiography can be used to assess distal perfusion.

Systemic empiric antibiotics are not indicated and are reserved for identified infections. Keep the wounds clean and leave uninfected blebs intact for up to 7 to 10 days to provide a sterile biologic dressing that protects underlying epithelialization. Tobacco, nicotine, and other vasoconstrictive agents must be withheld.

With all cold injuries, physical estimation of injury depth and tissue damage is not usually accurate until demarcation between live and dead tissue is evident. This often requires several weeks or months of observation. Dress these wounds regularly with a local topical antiseptic to help prevent bacterial colonization, and debride them once the demarcation has developed. There is some evidence that triple-phase bone scan can help identify the level of injury sooner than waiting for physical demarcation. Early surgical debridement or amputation is seldom necessary unless infection occurs.

HYPOTHERMIA

All injured patients are susceptible to hypothermia, and any degree of hypothermia can be detrimental. Hypothermia is commonly defined as core temperature below 35°C (95°F), and severe hypothermia as any core temperature below 32°C (89.6°F). Accidental hypothermia is determined by esophageal, bladder, or rectal temperature. The Swiss staging system provides a way to clinically determine the severity of hypothermia (■ **Table 9-3**).

HEATSTROKE

There are two types of hyperthermic injury that require consideration in the Primary Survey: exertional heatstroke and classic heatstroke. Exertional heatstroke typically occurs in younger individuals performing vigorous exercise in a hot environment. The heat generated from intense musculoskeletal activity cannot dissipate well, and leads to a rise in body temperature. In contrast, classic heatstroke results from prolonged passive exposure to heat, such as during heatwaves. Classic heatstroke is more common in older adults, and individuals with pre-existing comorbidities. The diagnosis of heatstroke is based on a triad of hyperthermia (40°C–43.6°C), altered central nervous system function, and exposure to extreme heat or exertion. The central nervous system alteration seen with heatstroke often presents rapidly, is nonfocal, and may include confusion, lethargy, or delirium.

Cooling should begin immediately in the prehospital setting and should be continued through transport and into the hospital setting (see ■ **Table 9-4**). Cool water immersion is the first-line intervention; cooling the patient should proceed to 38.9°C. Care for organ dysfunction is supportive.

■ **Table 9-3: Staging and Management of Hypothermia.** Systemic hypothermia must be recognized in the Primary Survey and treatment tailored depending on the severity. Any stage of hypothermia can result in coagulation abnormalities, leading to resuscitation challenges.

Staging and Management of Hypothermia

Stage	Symptoms	Core Temp.	Treatment
I	Conscious, shivering	32°–35°C	Warm environment and clothing, active movement, warm oral fluids
II	Impaired consciousness, no shivering	28°–<32°C	Cardiac monitoring, cautious movements to avoid arrhythmias, full-body insulation, active external and minimally invasive rewarming techniques (chemical, electrical, or forced-air heating packs or blankets, warm IV fluids)
III	Unconscious, vital signs are present	24°–<28°C	All the above plus: intubation, rewarming with extracorporeal support if available
IV	No vital signs	<24°C	All of the above plus: CPR and up to three doses of epinephrine and defibrillation, can continue if patient responds. Continue active external or internal rewarming if extracorporeal support not available

For stage IV, duration of resuscitation efforts should be based on locally available resources and protocols.

■ **Table 9-4: Treatment of Heatstroke/Hyperthermia.** Heatstroke can lead to organ dysfunction and death if not recognized and treated early. Although less common than hypothermia in trauma patients, it should still be excluded if patients present with injuries after exertion/working outside in hot environments.

Suspected Heatstroke

Assessment	Measure core temperature; if >40°C, heatstroke is likely
Immediate Cooling	1. Move patient to cooler environment 2. Begin external cooling: • Immerse in ice water • Place ice packs/cold towels at junctional vascular points (i.e., neck, axillae, groin) • Spray skin with water and continuously fan
Hospital Cooling	External cooling devices Intravascular cooling cannulas

CHAPTER SUMMARY

Thermal injuries should be assessed and treated following the primary and secondary survey framework. In the case of major burns, rapidly addressing the airway and initiating fluid resuscitation are important interventions to prevent patient deterioration. Burn fluid-repletion rates follow age-based criteria during prehsopital transport, and these are subsequently adjusted based on patient weight and extent once the injury TBSA is estimated. Following initial stabilization, consultations and transfer decisions to specialized burn care facilities should follow established guidelines.

KEY LEARNING POINTS

- **Stop the burning process.**
- **Burn inflammation/edema is progressive, and frequent reassessment of the airway or compartments is required.**
- **In the Primary Survey, fluid resuscitation is started at fixed rates based on age.**
- **In the Secondary Survey, adjusted fluid rates are calculated based on burn size and patient weight.**
- **Adjust fluids hourly based on patient response, beginning at hour 1.**
- **Electrical burns may be associated with occult (deep-tissue) injuries.**
- **Frostbite staging is akin to burn depth; initial treatment is by rewarming the affected area.**
- **The American Burn Association has issued guidelines for burns that typically require consultation and transfer to a regional center (see Table 9-2).**
- **Early management and treatment of hypo- and hyperthermia are an essential part of Initial Assessment.**

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10

Musculoskeletal Trauma

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Explain the significance of musculoskeletal injury as it relates to the patient's assessment during the primary survey
2. Identify and initiate treatment for musculoskeletal injuries that may result in threat to life or limb in the context of the ATLS algorithm
3. Be able to select and apply appropriate musculoskeletal adjuncts during the primary and secondary Survey
4. Describe the elements of the evaluation of the musculoskeletal injuries during the secondary Survey
5. Describe the signs and symptoms of compartment syndrome
6. Recognize associations between the mechanism of injury and specific musculoskeletal injury patterns
7. Recognize musculoskeletal injuries requiring timely transfer

10

Musculoskeletal Trauma

CHAPTER STATEMENT

It is estimated that up to 60% of traumatically injured patients sustain some form of musculoskeletal injury, which underscores the necessity for trauma care clinicians to adeptly identify and address these injuries within the broader context of trauma management. Musculoskeletal injuries may lead to chronic dysfunction and long-term morbidity, emphasizing the importance of timely and systematic identification and management of injuries at all severity levels for optimal long-term outcomes. Delayed recognition and treatment of these injuries can result in life-threatening hemorrhage, limb loss, and/or permanent impairment.

INTRODUCTION

In the management of trauma patients, musculoskeletal injuries represent a significant clinical concern due to their high prevalence and potential to complicate care. These injuries, while not explicitly categorized within the xABCDE algorithm, critically influence treatment priorities throughout the patient care process. Musculoskeletal injuries can range from life- or limb-threatening conditions to less-severe injuries that may nonetheless distract from more critical concerns.

Knowledge of the correlation between specific injury mechanisms and musculoskeletal injury patterns is crucial for anticipating potential injuries and guiding the judicious application of diagnostic imaging. Understanding the anatomical pathway and proximity of major neurovascular structures to these injuries is essential for assessing associated injuries and determining treatment approaches.

Significant injuries such as major pelvic-ring disruptions and femoral shaft fractures are particularly associated with the risk of substantial hemorrhage. The acute management of these injuries, including the application of pelvic binders and femoral traction splints, highlights the need for specialized knowledge in the stabilization of these critical conditions.

Additionally, conditions such as open fractures, fracture dislocations with neurovascular compromise, acute compartment syndrome, and major crush injuries can pose acute threats to patients' limbs. Moreover, musculoskeletal injuries that are not immediately life-threatening may pose a risk for long-term disability if not promptly and appropriately managed.

Prehospital information plays a pivotal role in optimizing care delivery and patient outcomes. A MIST (Mechanism of Injury or Illness, Injuries Sustained, Signs and Symptoms, Treatment)-style handover from prehospital care providers offers valuable insights into the mechanism of injury and potential musculoskeletal injuries, aiding in the preparation of necessary equipment, personnel, and resources. See ■ **Box 10-1** for a list of key considerations. Early communication with subspecialty teams, including orthopaedic, vascular, and plastic surgery, is critical for comprehensive care planning. **Awareness of local resources and the establishment of protocols for the timely transfer of patients requiring specialized care are essential components of effective trauma management.**

PATHOPHYSIOLOGY

The pathophysiology of musculoskeletal injuries, encompassing both fractures and soft-tissue damage, is fundamentally influenced by the mechanisms of injury. These mechanisms include blunt, penetrating, crush, and blast injuries. **The kinetics of the injury and the force applied to the tissues determine the severity of the injury**. Consider pedestrians struck by moving vehicles. The size of the vehicle (truck versus sedan) and size of the pedestrian can affect the site of impact and the injuries inflicted. In addition to the size, shape, and weight of the vehicle, the speed at which the impact occurred can also influence the nature of the injuries (■ **Figure 10-1**). These forces are applied across all tissue types, including bone, ligament, tendon, skin, muscle, vessel, and nerve. Failure to consider these injuries in the acutely injured patient can lead to significant disability. A high index of suspicion of injury to adjacent structures should be maintained.

INJURY MECHANISM

Blunt force trauma, such as falls, motor vehicle collisions, or direct blows, is a frequent cause of fractures. **The force required to break bones varies significantly across different bones and is influenced by the direction and magnitude of the force, the bone's size and density, and the individual's age.** For example, high-energy collisions produce considerable force and can lead to fracture of the femur, one of the strongest bones in the body. In contrast, much less force is required to fracture a clavicle, a much smaller subcutaneous bone.

Similarly, the energy required to create a comminuted or multifragmentary fracture is much greater than that required to create a simple fracture and implies a much larger zone of injury to both bone and soft tissue. ■ **Figure 10-2A** shows a simple fracture caused by a low-kinetic-energy mechanism, and ■ **Figure 10-2B** shows a multifragmentary fracture caused by a high-kinetic-energy mechanism. The threshold at which a bone fractures also depends on factors such as bone density; osteoporotic bones may fracture under much less force compared to healthy bones.

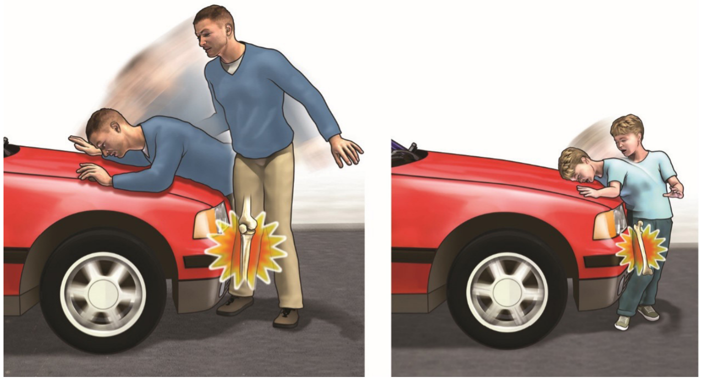
Blunt trauma can also cause a range of soft-tissue injuries, including contusions, sprains, and strains. The severity of these injuries depends on the force's magnitude and the affected tissue's resilience. High-energy impacts can cause severe sprains where ligaments are overstretched or torn, and strains where muscle fibers and tendons are damaged, leading to significant functional impairment.

■ Box 10-1: Important Prehospital Information and Findings.

Important Prehospital Information and Findings

- Type and speed of vehicle(s)
- Use of restraint devices or projective equipment
- Ejection
- Height of fall
- Explosion; magnitude; open or closed space
- The estimated time of injury, especially if there is ongoing bleeding or clinical deterioration, an open fracture, dislocation of a joint, and/or a delay in reaching the hospital
- Entrapment or delays in extrication or transport
- Bleeding or pooling of blood at the scene, including the estimated amount
- Time of tourniquet placement, if applicable, and the reason for application
- The position in which the patient was found at the scene and whether or not they were able to mobilise independently
- Visualized deformity
- Open wounds in proximity to visualized or suspected fractures
- Bone, joint, or fracture ends (or other deep structures) that may have been exposed, especially if they are no longer visible after initial care
- Was the open fracture sustained in a contaminated environment?
- Any compression mechanism that could result in a crush syndrome
- Presence or absence of motor and/or sensory function in each extremity
- Changes in limb function, perfusion, or neurologic state, especially after immobilization or during transfer
- Reduction of fractures or dislocations at the scene
- Dressings and splints applied, with special attention to pressure over bony prominences that can result in tissue trauma, neurovascular compression, or compartment syndrome
- Was the patient exposed to temperature extremes, chemicals, or radiation?

■ Figure 10-1: Impact points vary based on vehicle and individual, such as, height of bumper and patient's age and size.

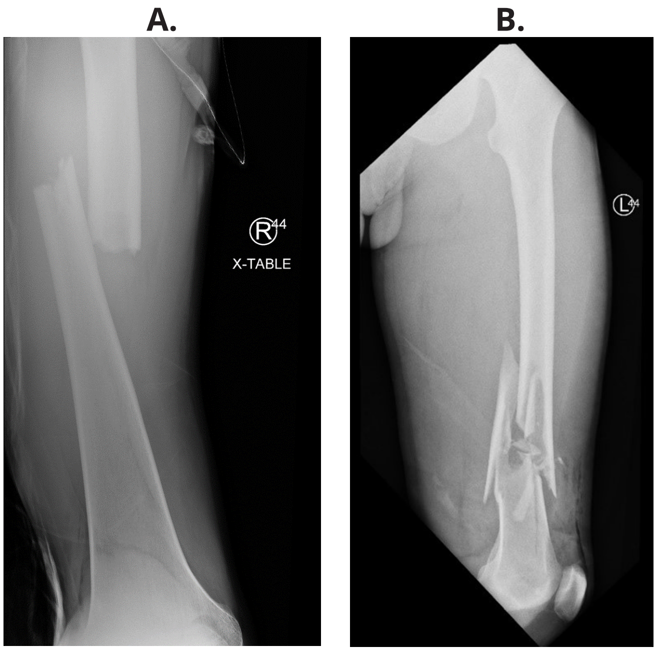


The force required to tear or dislocate soft tissues, such as ligaments and tendons, also varies. For instance, the anterior cruciate ligament in the knee may tear with a forceful impact on the leg and a sudden change in direction, common in sports injuries. Joint dislocations occur when the force applied overcomes the stability provided by the joint's ligaments, the capsule, and the congruence of the joint surfaces, such as a shoulder dislocation resulting from a fall on an outstretched hand.

Penetrating injuries, such as those caused by bullets or sharp objects, can lead to fractures with a severity that varies with the amount of kinetic energy transferred. Surrounding soft-tissue structures are also at risk, including muscles, tendons, nerves, and blood vessels.

Explosions can produce devastating injury, particularly when they occur in an enclosed space. Secondary blast injury results from shrapnel and debris that become high-velocity projectiles, causing penetrating or blunt-force injury. Tertiary blast injury results from the blast wind violently launching the patient into the ground or against objects, producing fractures and soft-tissue injury.

■ Figure 10-2: **A.** Plain x-ray of a femur demonstrating a simple fracture with displacement. **B.** Mutlifragmentary femur fracture. The distal femur rotated 90 degrees from the proximal femur. This injury represents higher-kinetic-energy mechanism.



Understanding the mechanisms of musculoskeletal injuries and the forces involved is crucial for diagnosis, management, and prevention strategies. The severity and complexity of these injuries necessitate a comprehensive approach to treatment, encompassing immediate care, possibly surgical intervention, and long-term rehabilitation to restore function and prevent long-term disability.

ASSESSMENT

PRIMARY SURVEY

POTENTIALLY LIFE-THREATENING MUSCULOSKELETAL INJURIES

During the primary survey, it is crucial to rapidly identify and manage hemorrhage from musculoskeletal injuries.

Hemorrhage from the pelvis and extremities, originating from major arteries, presents a critical challenge. Injuries to proximal limb vessels, such as the femoral or brachial arteries, carry a higher risk of severe bleeding. Without timely intervention, even minor arterial injuries can result in considerable blood loss, potentially leading to rapid clinical decline and exsanguination. **These injuries should be prioritized as the "x" element in the xABCDE algorithm, taking precedence over other clinical concerns. The primary objective is to "Stop the Bleed" employing multiple strategies. Initial measures include applying direct pressure, packing the wound, or possibly the application of a tourniquet. Correctly positioning and splinting limbs with active bleeding and associated fractures also assists in controlling hemorrhage.** Crush syndrome and traumatic fat embolism may develop after severe injuries and need to be considered.

An essential caveat for initial care clinicians is that a vascular injury without active bleeding should not overshadow the immediate management of life-threatening hemorrhage or other critical conditions. Such injuries, representing an ischemic threat to the limb, should be managed as a secondary priority following the stabilization of more urgent, life-threatening issues.

PELVIC FRACTURES

HEMORRHAGE CAUSED BY PELVIC FRACTURES

Pelvic fractures are potential sources of significant hemorrhage in patients who have sustained high-energy blunt trauma. This includes motor vehicle crashes, pedestrian injuries, and falls from heights. The bony pelvic ring is composed of the ilium, ischium, pubis, and sacral bones held together by sturdy ligaments. These bones are anatomically related to major vessels and nerves. Pelvic-related bleeding can arise from fractured bones, torn muscle, or associated veins and arteries. External signs of injury are often lacking. However, pelvic tenderness, ecchymosis over the pelvis, perineum, or scrotum, and sometimes a palpable diastasis of the symphysis pubis will be present.

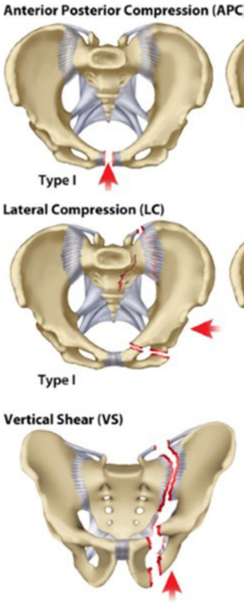
Pelvic fracture patterns can be differentiated into many classifications. **Any pelvic fracture pattern can produce significant hemorrhage. "Anterior posterior compression III" and "vertical shear" have been identified as the patterns most likely to require hemorrhage control interventions. Other factors identified as predictors of the need for hemorrhage control procedures include open pelvic fracture and age greater than 64.** It is most important to differentiate between hemodynamically stable and unstable patients. The nuances of the fracture patterns and methods for delineating mechanically stable fractures from unstable fractures are less important when a patient is actively bleeding. The World Society of Emergency Surgery has recommended that any patient who is hemodynamically unstable from a pelvic fracture be categorized as grade IV (**■ Table 10-1** and **■ Figure 10-3**) regardless of their fracture pattern. **Concomitant injuries may be present in up to 50% of patients with pelvic fractures.**

■ Table 10-1: This classification of pelvic fractures is based on the hemodynamic presentation of the patient. The classification and anatomic stability are of secondary importance. Treatment of hemodynamically unstable patients may include placing a binder, endovascular evaluation and treatment, preperitoneal packing, or bony stabilization. REBOA, resuscitative endovascular balloon occlusion of the aorta; WSES, World Society of Emergency Surgery.

WSES Grade	Description	Young-Burgess Classification	Hemodynamic Status	Mechanics	Early Treatment
I	Minor	APC I LCI	Normal	Stable	Routine evaluation
II	Moderate	LC II/III APC II/III	Normal	Unstable	Pelvic binder, possible angioembolization; possible external fixation or operative management
III	Moderate	VS	Normal	Unstable	Pelvic binder, possible angioembolization; operative management
IV	Severe	Any	Shock	Any	Pelvic binder, perperitoneal packing, mechanical fixation, REBOA, angioembolization

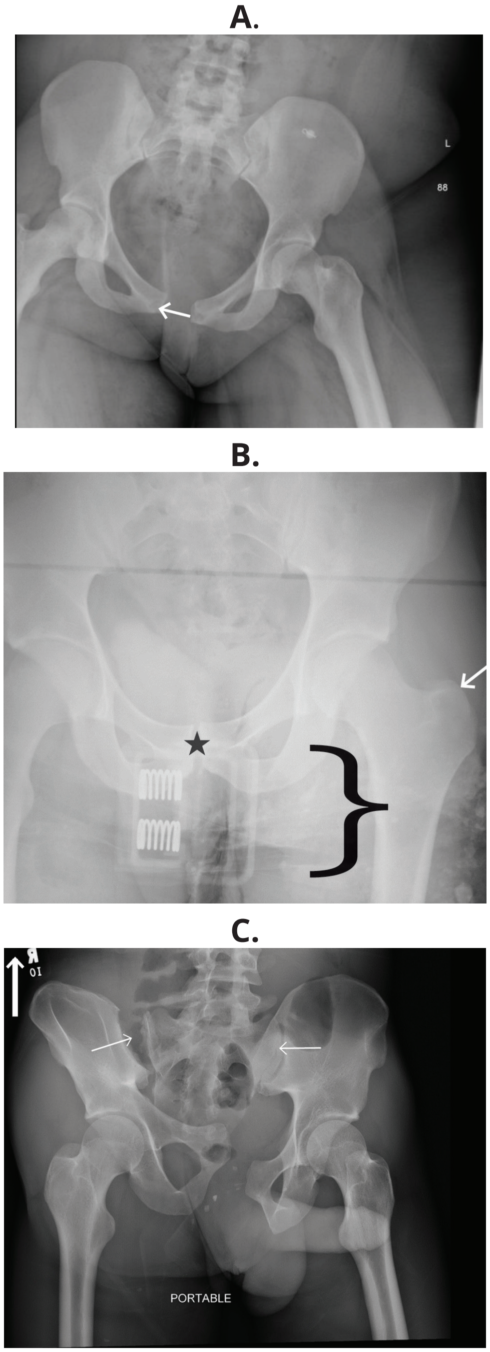
LC, lateral compression; APC, Anterior posterior compression; VC, Vertical shear; REBOA, Retrograde endovascular balloon occlusion of the aorta.

■ **Figure 10-3: Young-Burgess Classification of Pelvic Fractures.** Anterior-posterior compression fractures result from anterior to posterior force vectors which produce the characteristic pubic diastasis. They are graded in increasing severity from Type I to Type III. Lateral compression fractures are the most common class and result from lateral force vectors. Severity increases from Type I to Type III. Vertical shear fractures result from longitudinal forces. Sacral and sacroiliac injuries and shift of the hemipelvis superiorly are characteristic.



Aggressive distraction of the pelvis to assess for anatomic stability is discouraged, as it may increase bleeding. Rather, gentle anterior compression at the anterior superior iliac spine and lateral compression at the iliac crest can be performed. Pain, motion, or crepitus indicates fracture. Limb length discrepancy may be apparent and can indicate femur fracture or dislocation as well**. The pelvis can accommodate 4 to 6 liters of blood, so even isolated injuries can produce hemodynamic instability. If not already done by the prehospital care providers, the pelvis should be stabilized with a sheet or commercial binder.** The binder or sheet should be positioned circumferentially around the pelvis at the level of the greater trochanter of the femurs. This maneuver should internally rotate the limbs. The lower extremities can also be secured together at the ankles to further decrease the pelvic volume and limit bleeding. This maneuver prevents motion at the fracture site and can help tamponade venous bleeding to limit blood loss. This technique will be described further in the Circulation Skill Station section. **Blood loss from the pelvis is venous in 85% of cases, accounting for the success seen with compression. Hemostatic resuscitation that limits crystalloid, uses whole blood/blood products in low ratios, and administers TXA to patients within 3 hours of injury helps limit blood loss.** Pelvic and chest imaging and procedures to evaluate for intra-abdominal bleeding help determine next steps in management of the pelvic fracture bleeding. Urgent surgical consultation is important when managing these patients. Classic findings on imaging are shown in ■ **Figure 10-4A-C.**

■ **Figure 10-4: A.** Pelvic x-ray demonstrating widening of the symphysis pubis characteristic of YB AP compression fracture (note by arrow). YB, Young-Burgess; AP, Anterior-posterior compression. **B.** Pelvic x-ray of patient A after placement of pelvic-stabilizing device (binder). The star indicates position of pubic symphysis, the arrow is pointing to left greater trochanter and the bracket is outlining the pelvic stabilizing device (PSD). The PSD should be positioned below the greater trochanters. **C.** Vertical shear. Pelvic x-ray of a different patient with fracture through the SI joint with elevation of the right hemipelvis. Note thin red arrows identify the SI joints note widening on right and the wide arrow indicates elevation of the right hemipelvis. SI, Sacral Iliac.



Open pelvic fractures can result in rapidly exsanguinating hemorrhage. Thankfully, these injuries are not very common. These injuries usually require immediate packing and urgent surgical consultation.

MAJOR ARTERIAL INJURY AND TRAUMATIC AMPUTATION

In trauma care, a wide range of etiologies can precipitate major arterial injuries, including penetrating trauma, high-energy blunt forces, crush injuries, and mangled extremities. **Fractures or dislocations near an artery may also disrupt the vessel, leading to significant hemorrhage, either externally or contained within soft tissues. Patients experiencing traumatic amputation are at an elevated risk of life-threatening hemorrhage and may necessitate the early application of a tourniquet. In cases of major vessel damage, prompt referral to surgical services is typically imperative.**

ASSESSMENT

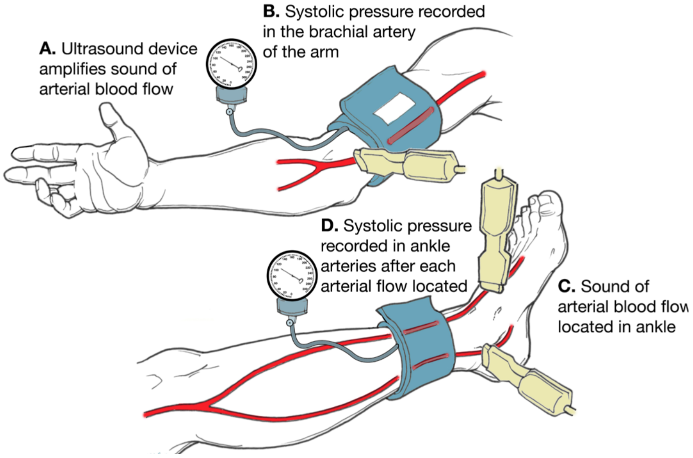
Assessment of injured extremities should include searches for both overt and subtle signs of bleeding, the absence or alteration of previously palpable pulses, and any asymmetry in pulse quality between limbs; any of these may indicate vascular injury. It's essential to mark the locations of palpable major distal pulses to aid subsequent evaluations. Utilizing Doppler ultrasound and measuring the ankle-brachial index (ABI) or injured extremity index (injured extremity compared to uninjured extremity) can be beneficial when resources permit. **The ABI is determined by dividing the highest systolic blood pressure obtained at the ankle by the systolic pressure at the brachial artery, with a ratio above 0.9 indicating normal perfusion in uninjured individuals (■ Figure 10-5). Differences in ABI between limbs may indicate arterial injury or compromise. Comparisons of systolic pressure can similarly be made between an injured and uninjured upper extremity (■ Figure 10-6).** CT angiography offers precise visualization of major vascular injuries and ongoing bleeding but is generally reserved for stable patients or to provide guidance for endovascular management. Associated fractures typically require realignment and provisional stabilization before definitive angiographic assessment.

It's crucial to remember that the presence of a Doppler signal alone does not exclude significant arterial injury. Signs such as expanding pulsatile hematomas, the absence of distal pulses, or visible arterial bleeding are definitive indicators of arterial damage.

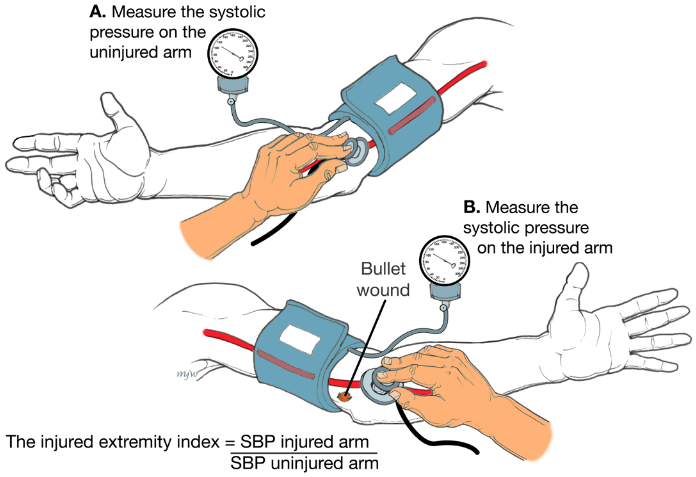
MANAGEMENT

In the absence of catastrophic bleeding, managing arterial hemorrhage starts with the immediate realignment of any limb deformities and the application of direct manual pressure to bleeding sites. A stepwise escalation in hemorrhage control measures may be necessary, potentially culminating in the application of a manual or pneumatic tourniquet **■ Figure 10-7** shows examples of commercial tourniquets. **Proper tourniquet application is vital to occlude arterial inflow without compromising the limb further, with careful documentation of the application time to guide future decisions on limb viability.**

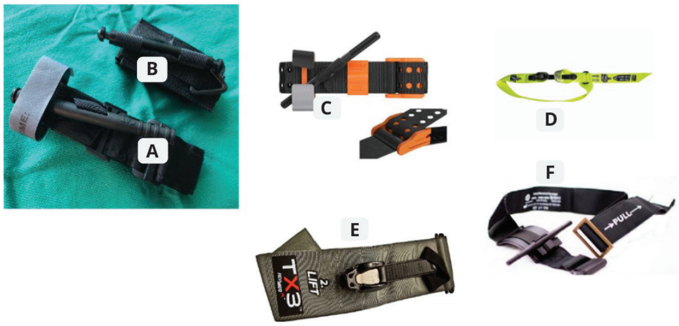
■ Figure 10-5: Ankle-Brachial Index (ABI) Measurement. **A.** A manual blood pressure (BP) cuff is insufflated on an uninjured UE to a pressure higher than the SBP and slowly deflated. **B.** A hand held doppler is used to detect the pressure at which flow returns. **C.** A manual BP cuff is insufflated on the affected leg to a pressure higher than the SBP and slowly deflated. **D.** A hand held doppler is used to detect the pressure at which flow returns. This pressure is compared to the pressure measured in the upper extremity. Values <0.9 are concerning for vascular injury.


A. Ultrasound device amplifies sound of arterial blood flow
B. Systolic pressure recorded in the brachial artery of the arm
D. Systolic pressure recorded in ankle arteries after each arterial flow located
C. Sound of arterial blood flow located in ankle

■ Figure 10-6: Injured Extremity Index. **A.** A manual BP cuff is insufflated on the uninjured upper extremity to a pressure higher than the SBP and slowly deflated. **B.** A hand-held doppler is used to detect the pressure at which flow returns. **C.** Repeat steps A. and B. on the injured UE. **D.** Calculate the IEI comparing the injured to the uninjured extremity. Values <0.9 are concerning for vascular injury. ABI, Ankle Brachial Index; BP, Blood pressure; SBP, Systolic blood pressure; IEI, Injured extremity index; UE, Upper extremity.


A. Measure the systolic pressure on the uninjured arm
B. Measure the systolic pressure on the injured arm
Bullet wound

The injured extremity index = $\frac{\text{SBP injured arm}}{\text{SBP uninjured arm}}$



■ **Figure 10-7: Several Tourniquet Models Are Commercially Available.** **A.** Combat application tourniquet (CAT). **B.** SOFTT or special operations forces tactical tourniquet. **C.** SAM XT from SAM Medical. **D.** Ratcheting medical tourniquet. **E.** TX 3 tourniquet. **F.** The tactical mechanical tourniquet TMT™. The Committee on Tactical Combat Casualty Care also known as CoTCCC or TCCC is the resource the Committee on Trauma's Stop the Bleed® Program utilizes for direction regarding equipment. These tourniquets are approved and listed on the TCCC's adjunct formulary, however not every version of the approved tourniquet is shown. A complete list can be found here: https://learning-media.allogy.com/api/v1/pdf/ef9c8ec7-c4b2-4948-9ff5-fb34f504032a/contents.

Tourniquets should be applied 2–3 inches (5–8 cm) above the area of injury and should not be placed over joints. Occluding only the venous system can increase hemorrhage and result in a swollen, cyanotic extremity. To achieve this effect, a pneumatic tourniquet may require pressures at 250 mm Hg or greater in an upper extremity and 400 mm Hg or greater in the lower extremity.

Remember that a large portion of the compressive effect of these high pressures is lost in compression of intervening tissue, and the observed torniquet pressure does not reflect the direct pressure on the vessel itself. **Ensure that the time of tourniquet application is clearly documented. Urgent surgical consultation is now essential, and early transfer to a trauma center with vascular surgical capabilities should be considered.** Limb viability is related not only to the extent of the original injury but also the subsequent ischemia time and the presence and depth of shock. Where torniquet times exceed 90–120 minutes, it may be appropriate to deflate the torniquet in a controlled manner to reassess ongoing bleeding and to decide the need to reinflate or use other hemorrhage control techniques. Extended tourniquet application time carries risks; thus, decisions to maintain or release a tourniquet depend on ongoing assessment of bleeding and the overall condition of the limb. See *Chapter 14, Initial Assessment: Secondary Survey*, for more regarding tourniquet conversion. A limb requiring a tourniquet is a threatened limb by definition.

Traumatic amputations usually benefit from early tourniquet use, typically applied in the prehospital setting. Management involves surgical consultation. While the possibility of replantation after complete amputation exists, it must be evaluated against the backdrop of the patient's overall injury profile and the viability of the amputated part. Typically, replantation is reserved for patients with isolated extremity injuries. Patients with multiple injuries requiring intensive resuscitation and/or emergency surgery may not be suitable candidates for surgical replantation. To ensure proper assessment, decision-making, and management, patients with traumatic amputations should be transferred to a surgical team experienced in replantation procedures. If feasible, the amputated part should be thoroughly cleansed with an isotonic solution (such as Ringer's lactate) and then wrapped in moist, sterile gauze.

Subsequently, encase the gauze-wrapped part in a moist, sterile towel, place it in a sealed plastic bag, and transport it alongside the patient in an insulated cooling chest filled with crushed ice. It is crucial not to immerse the amputated part directly in ice to avoid thermal damage (freezing), which could compromise its viability and potentially render it unsuitable for replantation, unless the receiving facility or surgical team provides specific instructions to the contrary. Traumatic amputations represent a profound physical and emotional event for patients, and psychological support is important in their assessment and management.

A limb showing deformity or circulatory compromise demands immediate realignment, splinting, and reassessment, as this might restore arterial flow. Always thoroughly assess and document the neurovascular status of an extremity before and after any intervention, as well as throughout your interaction with the patient, to ensure the best possible outcomes.

BILATERAL FEMUR FRACTURES

Patients with bilateral femoral shaft fractures or multiple long bone fractures face a significantly increased risk of complications and mortality. These injuries are indicative of exposure to substantial force. **Patients with bilateral femoral fractures are more susceptible to extensive blood loss, severe concurrent injuries, pulmonary complications, multiorgan failure, and death compared to those with a single femur fracture.** Isolated, closed femoral shaft fractures can lead to substantial blood loss, potentially reaching up to 2 liters, which, for a 70-kg patient, constitutes more than 40% of the total blood volume. Bilateral femoral fractures can result in twice this volume of blood loss. Open fractures cause rapid blood loss, leading to hemodynamic instability. The absence of a tamponading effect in open fractures can lead to life-threatening blood loss. Closed fractures may bleed more slowly but inevitably progress to hemorrhagic shock. **Therefore, splinting, applying traction, controlling local hemorrhage, and implementing careful resuscitation are crucial. Early transfer of such patients to a trauma center equipped with comprehensive orthopaedic surgical facilities is advisable.**

Appropriately treating, immobilizing, and resuscitating patients with multiple fractures reduces the risk of systemic complications. Fat embolism may still occur, however, when marrow enters the circulatory system and embolizes to the lungs. The acute pulmonary response to this embolus may be significant, especially if associated with ongoing hypovolemia.

POTENTIALLY LIMB-THREATENING MUSCULOSKELETAL INJURIES

Extremity injuries that do not immediately threaten life but jeopardize the acute or long-term viability of a limb are considered a secondary clinical priority, following the urgent needs of acute resuscitation and stabilization. This category encompasses open fractures, penetrating joint injuries, major joint dislocations, ischemic vascular injuries, compartment syndrome, and significant crush injuries, each of which warrants detailed attention as outlined subsequently. These injuries are critical and require timely identification and management to prevent severe outcomes or the potential loss of the affected limb. The decisions and assessments made during the initial evaluation of these injuries can significantly impact the patient's prognosis and eventual recovery trajectory.

OPEN FRACTURES AND PENETRATING JOINT INJURIES

Open fractures and penetrating joint injuries create a direct pathway between the external environment and the internal fracture zone or joint space (■ **Figure 10-8**). This condition arises when skin and any intermediate tissues, such as fascia or muscle, are compromised, with the extent of soft-tissue damage generally being proportional to the force of impact. **The resultant exposure, coupled with the risk of bacterial contamination, predisposes these injuries to complications such as infection, delayed healing, and functional impairment.** Immediate and thorough evaluation is essential for the management of these injuries.

ASSESSMENT

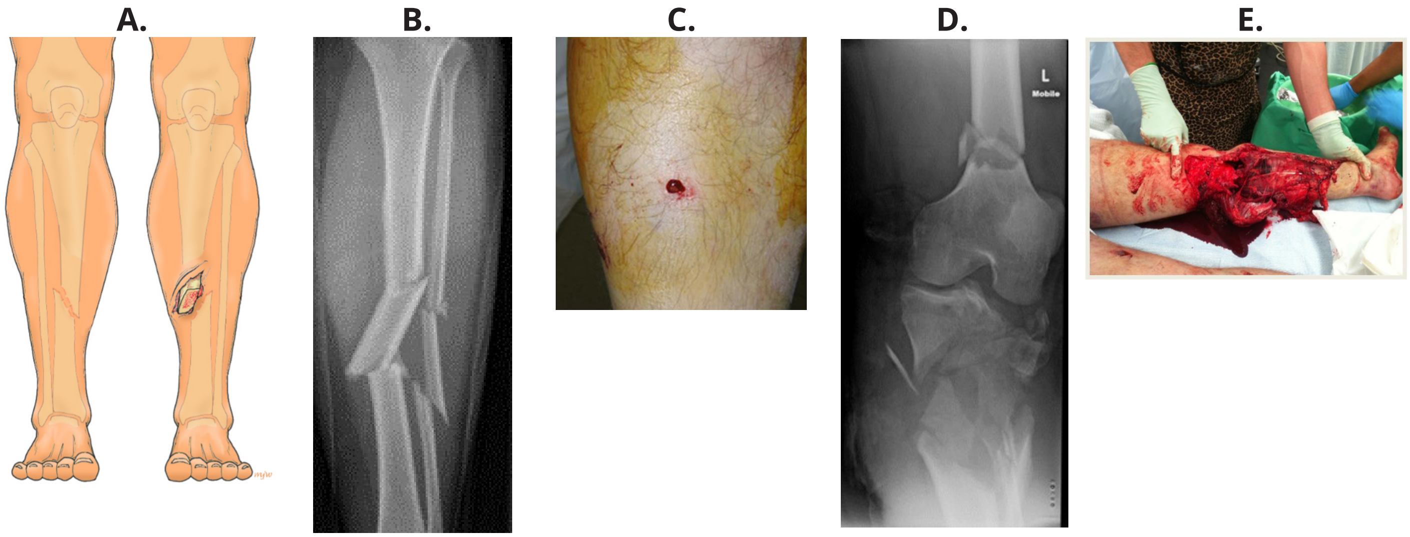
The identification of an open fracture or penetrating joint injury is critical and should be based on a thorough physical examination revealing any open wounds associated with a fracture. **Not every skin wound near a fracture signifies an open injury; however, a high index of suspicion is advisable, and erring on the side of treating such a wound as an open injury is typically safer.** Probing of wounds is discouraged during initial assessment to minimize the risk of infection, bleeding, and iatrogenic injury.

Documentation of the wound starts in the prehospital setting with a detailed description of the injury and any initial treatment. Visual evidence of a fracture end protruding through the skin is diagnostic of an open fracture. Suspected but not immediately apparent open-joint injuries may require CT scanning for confirmation. The detection of intraarticular gas on imaging studies is a reliable indicator of an open-joint injury and necessitates early orthopaedic consultation for possible surgical intervention.

Photographing injuries for documentation and referral can be beneficial when clinically appropriate and done with adherence to local guidelines. Such images assist in accurately conveying the injury severity to consulting services and aid in surgical planning while also serving legal documentation purposes. Patient consent for photography should be obtained where feasible, ensuring respect for patient privacy and dignity.

MANAGEMENT

Management strategies should be informed by a comprehensive review of the injury history and clinical assessment. **Administration of IV antibiotics is recommended for all patients with open fractures, prioritizing first-generation cephalosporins and other agents, as necessary based on the injury mechanism and local protocol** (■ **Table 10-2**). **Delaying**



■ **Figure 10-8: Open and Closed Tibial Fractures. A.** This diagram illustrates the difference between an open (left) and closed (right) tibial fracture. The open fracture shows bone protrusion through the skin, creating a risk for contamination and infection. The closed fracture has no skin breaks and the bone remains internal to the soft-tissue envelope. It is crucial to recognize open fracture to decrease the risk of infection. **B.** Radiograph of comminuted tibia and fibula fractures with multiple fragments. The distal portion of the tibial bone fragment abuts the skin. **C.** Photograph of right leg of patient from B. This image shows a small open wound on the skin overlying a tibial shaft fracture, indicating an open fracture. Even with minimal skin disruption, there is a risk of contamination and infection. Proper wound care, antibiotics, and surgical debridement are essential components of management for open fractures to prevent complications. **D.** This x-ray depicts a comminuted fracture of the distal femur with multiple fragmented bone pieces and severe displacement. Such fractures often result from high-impact trauma and may involve significant soft-tissue injury. **E.** Photograph of left leg of the patient from D. There is a severe open fracture of the distal femur and proximal tibia with extensive soft-tissue damage and bone exposure. The injury presents a high risk of contamination, infection and hemorrhage. Immediate management involves hemorrhage control, bony stabilization, administration of antibiotics, and thorough debridement.

■ **Table 10-2: Antibiotic Regimen for Open Fractures Based on Severity and Contamination.** Gustilo-Anderson open fracture classification grades open fractures on a scale from 1-3 based on the amount of contamination and degree of tissue compromise where type 1 is a clean wound with <1cm of length and type III is heavily contaminated with significant soft-tissue damage and vascular injury.

Preventative Antibiotic Regimens for Patients with Open Fractures

	Absence of potential soil or water contamination	Presence of potential soil contamination (in absence of water contamination)	Presence of water contamination
Gustilo-Anderson fracture type I or II			
Preferred regimen	Cefazolin 2g IV Q8H	Cefazolin 2 IV Q8H **PLUS** metronidazole 500mg IV Q8H **or** Ceftriaxone 2g IV Q24h **PLUS** metronidazole 500mg IV Q8H	No modifications needed to recommendations to left
Alternative regimen for beta-lactam hypersensitivity	Vancomycin • Loading dose 20mg - 35mg/kg • Maintenance dose 15mg–20mg/kg Q8-12H (dose based on patient-specific factors and adjust to trough levels)	Clindamycin 900 mg IV Q8H	No modifications needed to recommendations to left
Gustilo-Anderson fracture type III			
Preferred regimen	Cefazolin 2g IV Q8H **PLUS** gentamicin 5mg/kg IV Q24H **or** Ceftriaxone 2g IV Q24H	Ceftriaxone 2g IV Q24H **PLUS** metronidazole 500mg IV Q8H **or** Cefazolin 2g IV Q8H **PLUS** gentamicin 5mg/kg IV Q24H **PLUS** metronidazole 500mg IV q8H	Fresh water contamination: Piperacillin/Tazobactam 4.5g IV Q6H Salt-water contamination: Piperacillin/Tazobactam 4.5g IV Q6H **PLUS** doxycycline 100mg IV/PO Q12H
Alternative regimen for beta-lactam hypersensitivity	Clindamycin 900mg IV Q8H	Clindamycin 900mg IV Q8H **PLUS** gentamicin 5mg/kg IV Q24H	Fresh water contamination: Imipenem 500mg IV Q6H **or** Meropenem 1g IV Q8H Salt-water contamination: Imipenem 500mg IV Q6H **or** Meropenem 1g IV Q8H **PLUS** Doxycycline 100mg IV/PO Q12H

Notes:
- If cefazolin is to be used, use 3 g IV Q8H in patients >120 kg
- For patients at risk for MRSA (methicillin-resistant Staphylococcus aureus), gram-positive coverage should consist of vancomycin instead of cefazolin
- Can use fluoroquinolone (levofoxacin, ciprofloxacin) in place of doxycycline
- Prophylactic ABX can be discontinued 24 hours after wound closure for Type I and II fractures and after 72 hours for Type III fractures
- Systemic ABX recommended to be initiated at time of diagnosis
- Gram-positive coverage ASAP after injury and addition of gram-negative coverage for Gustilo-Anderson Type III open fractures

antibiotic treatment beyond 3 hours postinjury increases the risk of infection. Ideally, antibiotics should be administered within 1 hour of arrival to the emergency department.

Early removal of contaminants using sterile instruments and covering the wound with a moist, sterile dressing can be performed in the emergency department. This is followed by stabilizing the injury after a detailed assessment that includes evaluating the soft tissue, circulation, and neurological status. Orthopaedic surgical consultation should be sought without delay. Tetanus prophylaxis is advised for all significant open musculoskeletal trauma unless history of recent vaccination is verified or administration is contraindicated (■ **Table 10-3**).

VASCULAR INJURIES

When patients present with signs of vascular insufficiency following blunt, crushing, twisting, or penetrating injuries or following dislocations of an extremity, vascular injury should be a primary concern. Should significant hemorrhage be detected, immediate management should follow the protocols for life-threatening injuries as previously outlined.

■ **Table 10-3: Age-Based Tetanus Immunization Recommendations.**

Age-Based Tetanus Immunization Recommendations

Age (years)	Vaccination history	Clean, minor wounds	All other wounds
0 - 6	Unknown or up to date on DTaP series based on age	DTaP	DTaP TIG
	Up to date on DTaP series based on age	No indication	No indication
7 - 10	Unknown or incomplete DTaP series	Tdap and recommend catch-up vaccination	Tdap and recommend catch-up vaccination TIG
	Completed DTaP series AND ≤ 5 years since last dose	No indication	No indication
	Completed DTaP series AND ≥ 5 years since last dose	No indication	Td, but Tdap preferred if child is 10 years of age
11 + **(If pregnant, see footnote)**	Unknown or < 3 doses of tetanus toxoid containing vaccine	Tdap and recommend catch-up vaccination	Tdap and recommend catch-up vaccination TIG
	3 or more doses of tetanus toxoid containing vaccine AND < 5 years since last dose	No indication	No indication
	3 or more doses of tetanus toxoid containing vaccine AND 5-10 years since last dose	No indication	Tdap preferred (if not yet received) or Td
	3 or more doses of tetanus toxoid containing vaccine AND > 10 years since last dose	Tdap preferred (if not yet received) or Td	Tdap preferred (if not yet received) or Td

*Pregnant patients: As part of standard wound management care to prevent tetanus, a vaccine containing tetanus toxoid might be recommended for wound management in a pregnant woman if 5 years or more have elapsed since the previous Td booster. If a Td booster is recommended for a pregnant patient, healthcare providers administer Tdap. Source: https://www.cdc.gov/disasters/disease/tetanus.html. TIG, tetanus immune globulin.

ASSESSMENT

Extremities may initially seem viable due to collateral circulation, which can maintain some blood flow. However, nonocclusive vascular injuries, such as intimal tears or compression by external forces, can lead to symptoms of coolness, delayed capillary refill, reduced peripheral pulses, and an abnormal ABI. In cases where there is a complete disruption of blood flow, the limb may appear cold, pale, and pulseless, signaling an urgent need for medical intervention. While not immediately life-threatening, timely recognition and management of these symptoms are critical to prevent irreversible damage. Early surgical intervention for revascularization may be necessary to restore blood flow and prevent muscle necrosis and nerve damage, which can begin within hours of arterial disruption.

MANAGEMENT

It is critical to recognize that perfusion of an injured limb cannot be adequately assessed until length, alignment, and rotation of the limb have been restored. For dislocations and fractures, gentle realignment of the limb to its natural length and position to match the uninjured side, followed by splinting, can often restore blood flow, especially when arterial compression is due to fracture displacement. Initially perfect anatomic alignment is not necessary. The goal is to restore the general course of the nerves and vessels and to relieve pain.

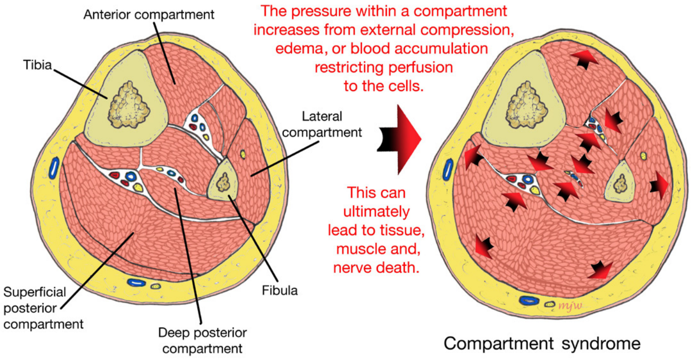
In cases where arterial injury is coupled with major joint dislocation, carefully attempt reduction or splint the joint as is and obtain orthopaedic surgical consultation. While CT angiography is a valuable diagnostic tool for assessing vascular injuries, it should not postpone the restoration of blood flow and is best utilized following surgical consultation.

Splinting of an injured limb carries a risk of vascular compromise; therefore, a thorough neurovascular assessment is essential before and after any splinting or immobilization. Any decrease in pulse strength or increase in pain after splinting should be immediately reevaluated. Circumferential dressings, casts, or splints that compromise vascular integrity should be loosened or removed to reassess and document blood supply, ensuring the limb's viability is not endangered.

COMPARTMENT SYNDROME

Compartment syndrome develops when increased pressure within an unyielding anatomical space causes ischemia, vascular congestion, and subsequent anoxic and metabolic injury. This condition can rapidly progress to tissue death if not treated promptly. The increased pressure can stem from factors like internal bleeding or swelling from injury or revascularization of an ischemic limb, or externally from tight dressings that limit compartment volume. **Although commonly seen within myofascial compartments of the limbs, the presence of an intact fascial barrier is not a prerequisite for compartment syndrome. The skin alone can act as a restricting layer, and compartments can still be compromised in the presence of open fractures. Common areas at risk for compartment syndrome after injury include the lower leg, forearm, foot, hand, thigh, and gluteal regions. ■ Figure 10-9 demonstrates the pathophysiology of compartment syndrome.**

■ Figure 10-9: Pathophysiology of Compartment Syndrome in the Lower Leg. The cross-sectional view shows the anterior, lateral, superficial posterior, and deep posterior compartments of the lower leg. Increased pressure within one or more compartments, due to external compression, edema, or internal bleeding, restricts perfusion and leads to decreased oxygen delivery to tissues. If left untreated, the sustained pressure compromises muscle, nerve, and vascular function, resulting in tissue ischemia and necrosis. Early recognition and intervention are crucial to prevent irreversible damage.


Anterior compartment
Tibia
The pressure within a compartment increases from external compression, edema, or blood accumulation restricting perfusion to the cells.
Lateral compartment
This can ultimately lead to tissue, muscle and, nerve death.
Superficial posterior compartment
Fibula
Deep posterior compartment
Compartment syndrome

ASSESSMENT

Pain is the earliest indication of compartment syndrome. Pain disproportionate to the injury, pain unrelieved by analgesics, and pain upon stretching the affected muscles are characteristic findings in patients with acute compartment syndrome (**■ Box 10-2**). Acute compartment syndrome is a clinical diagnosis based on the mechanism of injury and observation of the above clinical signs.

■ Box 10-2: Signs and Symptoms of Compartment Syndrome.

Signs and symptoms of compartment syndrome

- **Pain greater than expected** and out of proportion to the stimulus or injury
- **Pain on passive stretch** of the affected muscle
- **Tense swelling** of the affected compartment
- **Paresthesias or altered sensation** distal to the affected compartment

Early and accurate diagnosis is vital to prevent severe consequences, such as permanent nerve damage, muscle death, contractures, infection, delayed bone healing, and possibly amputation. High-risk factors for developing acute compartment syndrome include the following:

- Fractures of the tibia and forearm
- Injuries under tight casts or bandages
- Severe crush injuries
- Localized, prolonged external pressure (encircling casts, tourniquets, or dressings)
- Increased permeability following ischemia
- Circumferential burns
- Extravasation from intravascular infusions

Diagnosis should not wait for the appearance of late signs like diminished capillary refill, loss of sensation, or absence of pulses, as these may indicate irreversible damage. Patients with spinal cord injuries, major peripheral neurological injuries, multiple concomitant injuries, altered mental status, or heavy sedation or chemical paralysis may have unreliable clinical examinations, making the diagnosis of compartment syndrome more challenging. In these situations, direct measurement of intracompartmental pressures may be helpful in supporting the clinical diagnosis of compartment syndrome.

Compartment pressures exceeding 30mmHg suggest compromised blood flow, possibly warranting urgent medical intervention. Delta P calculation is more patient specific: the difference between the measured diastolic blood pressure of the affected limb and the measured compartment pressure is calculated. A value less than 30 mm Hg heightens the concern for compartment syndrome.

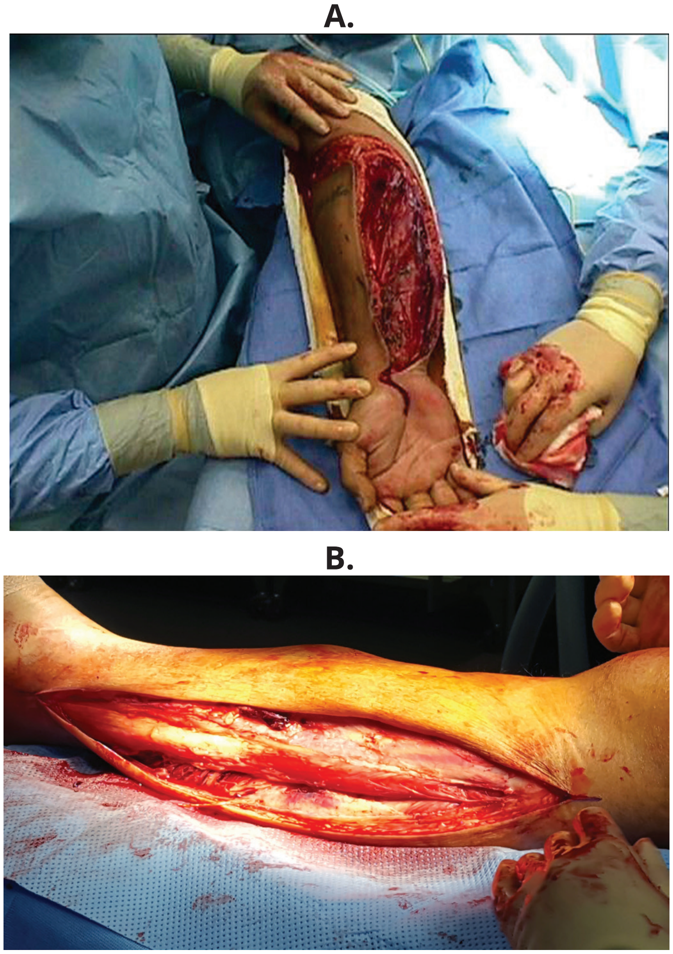
These findings may be challenging to distinguish from those expected in a traumatically injured patient, even for experienced professionals. Any concern for compartment syndrome should be escalated to a more experienced clinician or specialist consultation. Consider transfer if expertise is not available locally.

MANAGEMENT

The management of compartment syndrome is time-sensitive and requires frequent reexamination. Compartment syndrome is a dynamic process and may change with fluid shifts, ongoing bleeding, and progressive tissue edema; higher and prolonged pressures within the compartment can cause extensive neuromuscular damage. Immediate surgical consultation for a fasciotomy (■ Figures 10-10A and B are operative photos following decompressive fasciotomy) is the definitive treatment to relieve pressure and prevent permanent damage. Early intervention is crucial, and any constrictive materials should be removed to assess and improve blood flow.

Given that pain out of proportion is a hallmark finding in compartment syndrome, a careful approach to pain management is necessary in those who are at risk. Interventions that could mask an evolving compartment syndrome—such as regional anesthesia—should be avoided if possible. Clinicians should be aware of the potential complexities in diagnosing compartment syndrome amidst multiple injuries or sedation, underscoring the need for vigilance and a high index of suspicion.

■ Figure 10-10: Fasciotomy of the Extremities.
A. Operative photo of fasciotomy of the forearm. The volar aspect of the arm is shown with a long skin incision. The subcutaneous fat and fascia are opened and the fascia overlying the muscles is opened to relieve any constriction to perfusion to the muscles and nerves. **B. Operative photo of fasciotomy of the lower leg.** The medial incision is pictured with release of the superficial and deep posterior compartments. The skin, subcutaneous fat, and fascia have been widely opened. The fascia surrounding the muscles has been released to allow perfusion of the tissues.



CRUSH SYNDROME/REPERFUSION SYNDROME

Crush syndrome, also known as traumatic rhabdomyolysis, encompasses the systemic and renal complications arising from significant muscle damage. This condition typically follows a compression injury to a large muscle group, such as the thigh or calf, and involves a complex interplay of direct muscle trauma, ischemia, and necrosis. **These injuries result in the release of myoglobin and other cellular contents into the circulatory system, which can precipitate acute renal injury, systemic inflammation, metabolic derangements, and shock. A critical aspect of this syndrome is the rapid release of electrolytes and byproducts of anaerobic metabolism, which can disrupt cardiac conduction and neural function.** A notable risk is the sudden increase in potassium levels during reperfusion, which can trigger life-threatening cardiac arrhythmias.

In the prehospital context, it is crucial for medical professionals to recognize the potential for crush syndrome based on the mechanism of injury and maintain a high index of suspicion. Information on the duration and nature of compression, as well as the total ischemic time, is valuable, especially in cases of entrapment, such as motor vehicle accidents with cabin intrusion.

ASSESSMENT

Diagnostically, myoglobin release is indicated by dark amber urine that tests positive for hemoglobin, and a serum creatine kinase level exceeding 10,000 U/L serves as a marker for rhabdomyolysis in the absence of urine myoglobin measurements. Rhabdomyolysis can lead to metabolic acidosis, hyperkalemia, hypocalcemia, and coagulation abnormalities. These disturbances may compound the risks associated with shock, blood loss, and the need for massive transfusion.

MANAGEMENT

Early administration of IV fluids is essential for mitigating renal damage and preventing acute renal failure. However, the approach to fluid resuscitation must be carefully balanced against the risks of exacerbating hemorrhage, particularly in trauma patients with ongoing bleeding. Overly aggressive fluid resuscitation can potentially dislodge clots, dilute coagulation factors, and worsen bleeding.

Although there is no consensus on the use of bicarbonate therapy for intravascular alkalization in the initial management of severe trauma patients, it may have a role in later stages of care under the guidance of experienced critical care personnel. Balancing the dual priorities of trauma resuscitation and renal protection underscores the complexity of managing crush syndrome in severely injured patients.

COMMON MUSCULOSKELETAL CAUSES OF PERMANENT IMPAIRMENT

CONTUSIONS AND LACERATIONS

When evaluating simple contusions and lacerations, it's essential to consider the potential for overlooked vascular or neurologic damage. Generally, lacerations necessitate cleaning, appropriate debridement, and suturing. Lacerations penetrating below established fascial layers may warrant surgical exploration to thoroughly evaluate for deeper structural harm. Contusions, typically marked by localized pain, swelling, and tenderness, are initially managed by restricting movement of the affected area and applying ice.

Crushing injuries and internal degloving might not be immediately apparent and may be suspected from the injury mechanism alone. Crush injuries can lead to muscle devascularization and necrosis, while soft-tissue avulsion injuries may separate skin from underlying fascia or its vascular supply, potentially leading to skin necrosis or accumulation of blood or fluid (Morel-Lavallee lesion). Signs such as overlying abrasions or bruising might indicate severe muscle damage or the risk of complications like compartment syndrome. In cases of significant concern, surgical consultation for potential drainage or debridement is advisable.

The tetanus infection risk escalates with wounds that are older than 6 hours, deeply contused or abraded, deeper than 1 cm, or resulting from burns or high-velocity impacts. Wounds with heavy contamination, local tissue denervation, or ischemia also pose a higher risk. It's important to assess tetanus immunization status in these scenarios.

It's critical to note that the clinical presentation of significant contusions can evolve over time, and initial assessments might not fully reflect the injury's severity. Documentation of contusions' locations and sizes at the first evaluation is vital, with periodic reevaluation recommended. Sometimes, deep bleeding may not become visually apparent at the skin level for hours or even days.

NEUROLOGICAL INJURY SECONDARY TO FRACTURE OR DISLOCATION

Displaced fractures and those involving joint dislocations are at a heightened risk for causing neurological injuries due to the close anatomical relationship with major nerves. For example, a posterior hip dislocation can compress the sciatic nerve, and an anterior shoulder dislocation can injure the axillary nerve. These nerves may be damaged by blunt distracting forces or when they traverse from one anatomical compartment to another, leading to conditions like neuropraxia or direct compression injuries.

ASSESSMENT

Early and accurate identification of these injuries is crucial for optimal recovery, emphasizing the need for a focused neurologic examination in patients with musculoskeletal injuries. Establishing a baseline of neurological function and monitoring for any changes are key steps in the assessment. This often involves evaluating motor function and sensation in a structured manner for significant peripheral nerves, which requires patient cooperation. ■ **Table 10-4** describe the injuries that may be associated with nerve injury and diagnostic cues. Additionally, muscle testing should be performed, including palpation of the contracting muscle.

In cases of polytrauma, initial nerve function assessment can be challenging but should be revisited frequently, particularly after patient stabilization. Documenting any progression in neurologic symptoms is vital, as it may indicate ongoing nerve compression and can influence surgical decisions.

MANAGEMENT

Managing these injuries includes aligning and immobilizing the affected bones and joints. Experienced clinicians might also attempt to reduce dislocations and subsequently reassess neurologic function and immobilization of the limb. It is essential to inform the subsequent care clinician about the dislocation and its successful reduction.

Before any treatment or intervention, thoroughly assessing and documenting the distal neurovascular status of the injured extremity is imperative. This is because a limb that exhibits dysesthesia (abnormal sensation) post manipulation, without a prior assessment of its neurovascular status, poses a diagnostic challenge in distinguishing whether the nerve dysfunction was caused by the initial injury or the medical intervention.

■ **Table 10-4: Peripheral Nerve Assessment of the Extremities.** This table lists nerves that may be injured in association with upper- and lower-extremity fractures or dislocations.

Peripheral Nerve Assessment				
UPPER extremities	**Nerve**	**Motor**	**Sensation**	**Injury**
	Ulnar	Index and little finger abduction	Little finger	Elbow injury
	Median distal	Thenar contraction with opposition	Distal tip of index finger	Wrist fracture or dislocation
	Median, anterior interosseous	Index tip flexion	None	Supracondylar fracture of humerus (children)
	Musculocutaneous	Elbow flexion	Radial forearm	Anterior shoulder dislocation
	Radial	Thumb, finger metacarpophalangeal extension	First dorsal web space	Distal humeral shaft, anterior shoulder dislocation
	Axillary	Deltoid	Lateral shoulder	Anterior shoulder dislocation, proximal humerus fracture
LOWER extremities	**Femoral**	Knee extension	Anterior knee	Pubic rami fractures
	Obturator	Hip abduction	Medial thigh	Obturator ring fractures
	Posterior tibial	Toe flexion	Sole of foot	Knee dislocation
	Superficial peroneal	Ankle eversion	Lateral dorsum of foot	Fibular neck fracture, knee dislocation
	Deep peroneal	Ankle/toe dorsiflexion	Dorsal first to second web space	Fibular neck fracture, compartment syndrome
	Sciatic nerve	Ankle dorsiflexion or plantar flexion	Foot	Posterior hip dislocation
	Superior gluteal	Hip abduction	Upper buttocks	Acetabular fracture
	Inferior gluteal	Gluteus maximus hip extnesion	Lower buttocks	Acetabular fracture

JOINT AND LIGAMENT INJURIES

The mechanism of injury plays a pivotal role in the assessment of acute joint injuries. Patients might describe experiencing unusual forces acting upon the joint at the time of injury, such as a direct blow to the front of the knee (e.g., knee hitting the dashboard in a vehicle collision) leading to posterior subluxation of the knee, an ankle twisting due to an awkward landing from a jump resulting in damage to the lateral ligament complex, or an injury caused by falling onto an outstretched hand that forces the elbow into hyperextension.

ASSESSMENT

Upon physical examination, the injured joint typically shows tenderness. Presence of hemarthrosis (bleeding within the joint) is common, except when the joint capsule is torn, which allows blood to spread into surrounding soft tissues. Testing for ligamentous integrity through passive movements may demonstrate significant instability. X-ray imaging might not show major abnormalities but could reveal minor avulsion fractures at the sites where ligaments attach to bones.

MANAGEMENT

It is crucial to immobilize the joint and regularly monitor vascular and neurological function below the level of the injury. **Knee dislocations, for example, often spontaneously reduce to a position close to normal anatomy and might not be immediately obvious. In cases of knee injuries involving multiple ligaments, there may have been a dislocation that could pose a risk of neurovascular compromise. Such injuries typically necessitate a surgical consultation for proper stabilization of the joint.** Careful assessment of the vascular status of the limb is warranted.

ISOLATED FRACTURES

Fracture patterns can convey information about the forces involved at the time of the injury. Accurate description of the identified fractures is important. Elements of the description should include the bone and segment involved (i.e., diaphyseal, metaphyseal, or intraarticular), the character of fracture (i.e., simple or comminuted), and the pattern of the fracture (i.e., transverse, spiral, oblique, or complete versus incomplete).

ASSESSMENT

Pain, tenderness, swelling, and deformity are the hallmarks of extremity-fracture diagnosis. It is not necessary to elicit abnormal mobility or crepitus, as these maneuvers increase pain and soft-tissue injury.

MANAGEMENT

Immobilization of the fracture requires inclusion of the joints above and below the fracture. Neurovascular status is assessed before and after splinting. Orthopaedic consult is obtained for definitive management.

ADJUNCTS

FRACTURE IMMOBILIZATION

The primary aims of initially immobilizing a fracture are to realign the affected limb to its natural anatomical position as accurately as possible and to minimize movement at the fracture site to prevent further injury. In situations involving open fractures, attempting reduction can lead to the repositioning of previously exposed bone ends within the wound, necessitating thorough documentation of any bone exposure or skin penetration due to the potential for changes in visibility upon subsequent examinations. **Immediate cleansing of the wound to remove contamination, prompt administration of antibiotics based on the patient's weight, and a tetanus booster are critical for patients with open fractures or significant soft-tissue injuries.**

In cases of joint dislocations, some healthcare clinicians may be skilled and confident enough to attempt closed reduction. If the joint is successfully realigned, it should be immobilized using well-padded prefabricated splints, pillows, or casts to keep the limb in its corrected position. Should the reduction attempt fail, splint it in its current position.

It's crucial to prioritize life-saving interventions over splinting for extremity injuries, except in scenarios where hemodynamic instability is caused by femoral shaft fractures. Here, fracture reduction might be integral to the resuscitation process, falling under efforts to restore circulation. Additionally, the neurovascular status of the injured extremity must be thoroughly evaluated and documented both before and after any manipulation or splinting to ensure no additional harm is caused.

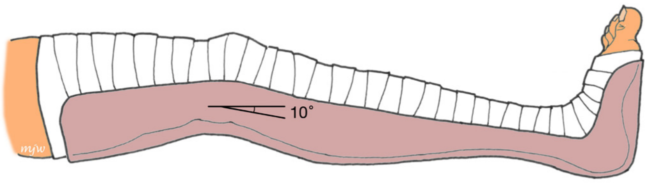
Reducing dislocations and reducing and splinting fractures will ultimately make these injuries less painful, but it is important to remember that these maneuvers will likely produce significant pain. The process should be explained to the patient and adequate analgesia provided.

Special caution is advised in cases with concurrent unstable pelvic injuries, disruptions at the splint's fixation points, additional fractures below the femoral shaft fracture, partial or complete amputation of the distal extremity, or limbs that have been deemed nonviable. In such scenarios, alternative methods of immobilization and care must be considered to avoid compromising the limb's neurovascular integrity.

PRINCIPLES OF SPLINTING AND IMMOBILIZATION

In general, for long bone injuries, appropriate immobilization requires inclusion of the joints above and below the fractured long bone. For joint injuries, immobilization of the bones above and below the joint is necessary to fully immobilize the injured area. Functionally appropriate alignment of the joint or limb should be maintained as much as possible. For example, for knee injuries, application of a posterior long-leg plaster back slab can be an effective means of maintaining comfort and stability of the knee. Where possible, immobilize the knee not in complete extension but with approximately 10 degrees of flexion to reduce tension on the posterior neurovascular structures (■ **Figure 10-11**).

■ **Figure 10-11: Stabilization of a Lower-Extremity Injury.** This figure demonstrates the application of a long-leg posterior splint for stabilization of a lower-extremity injury. The splint provides immobilization by extending from the foot to the thigh, maintaining the knee at a slight flexion angle of approximately 10 degrees. Proper padding and secure wrapping ensure that the limb is supported while minimizing movement, reducing pain, and preventing further damage to surrounding tissues. This technique is particularly useful for managing fractures, ligament injuries, or severe soft-tissue damage in the lower extremity before definitive treatment.



FEMUR FRACTURES

To immobilize femoral shaft fractures, apply inline traction to straighten the limb, then place an immobilization device to maintain alignment (■ **Figure 10-12**). Traction splints can be used for this purpose. These devices, designed specifically for femoral shaft (diaphyseal) fractures, apply force distally at the ankle and are positioned proximally against the major gluteal crease to reflect the ischial tuberosity's surface marking. It's crucial to note that traction splints are not suitable for all injuries and may be harmful or of limited value for conditions like associated pelvic fractures, femoral neck or peritrochanteric fractures, or concurrent ipsilateral tibial and femoral fractures, often referred to as a "floating knee."

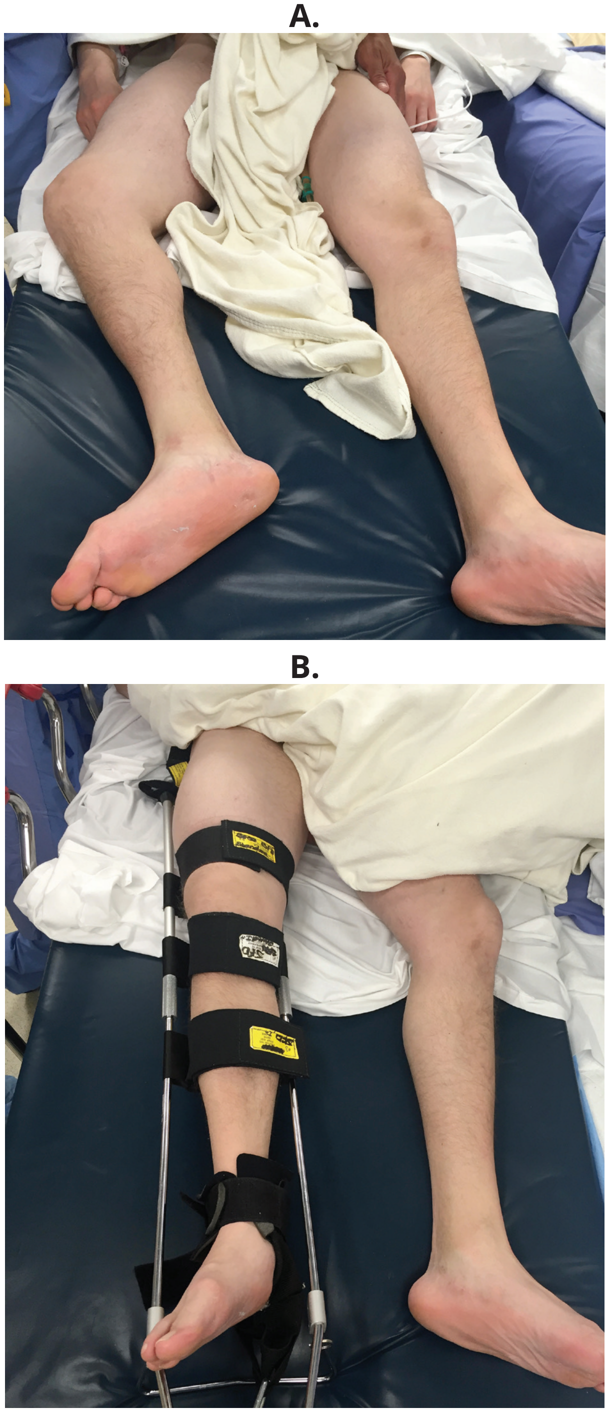
Before applying a traction splint, the patient's distal neurovascular status must be assessed and documented. While traction splints are not meant for definitive fixation or to achieve perfect anatomical reduction, their correct application aims to better align the limb and reduce fracture-related bleeding by minimizing potential bleeding space and applying tamponading pressure. However, excessive traction can damage the skin or exacerbate neurovascular compromise. If worsening of neurovascular status is noted after splint application, the traction should be reduced, or the splint may need to be removed and the limb repositioned to restore distal pulses.

In situations where a traction splint is not available or not feasible, the leg may be immobilized by a long plaster splint extending from ankle to waist, or even splinted to the intact contralateral leg.

OTHER FRACTURES

For fractures of other long bones, while acute reduction and stabilization of the reduced position are necessary, continuous traction may not always be required. Employing properly shaped or well-fitting splints can aid in managing blood loss, alleviating pain, and safeguarding against additional neurovascular and soft-tissue damage. Immobilize tibial fractures to minimize pain and further soft-tissue injury and decrease the risk of compartment syndrome. If readily available, well-padded plaster splints immobilizing the lower thigh, knee, and ankle are preferred (■ **Figure 10-11**).

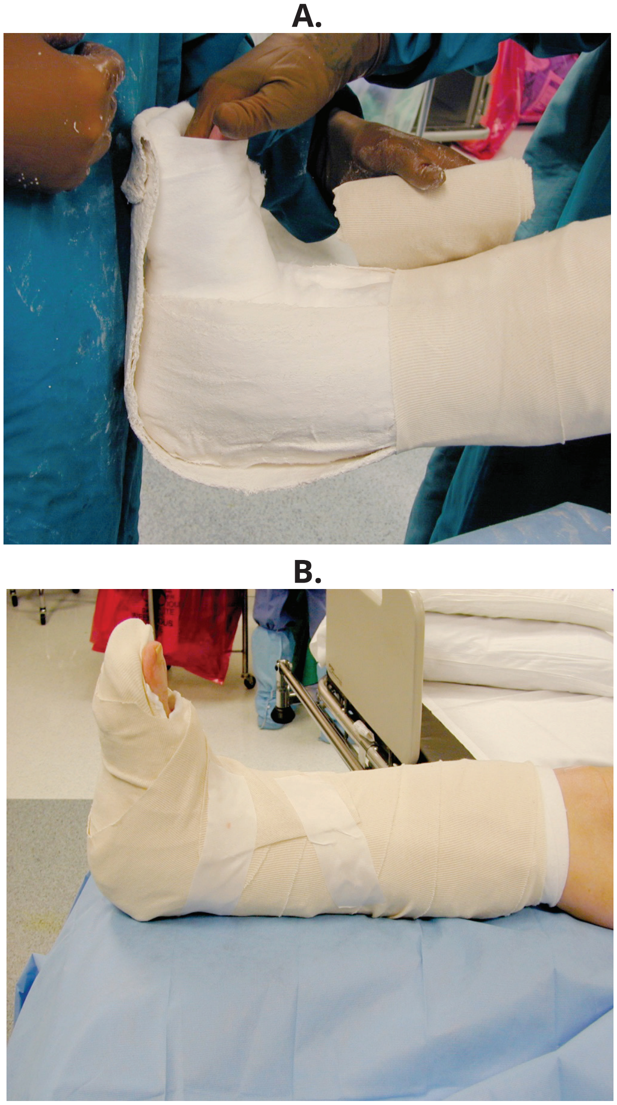
■ **Figure 10-12: Initial Fracture Immobilization.** The goal of initial fracture immobilization is to realign the injured extremity in as close to anatomic position as possible and prevent excessive fracture-site motion. **A.** Shortening and external rotation of right leg due to a mid-shaft femur fracture. **B.** Application of inline traction with stabilization of the leg in normal anatomic position.



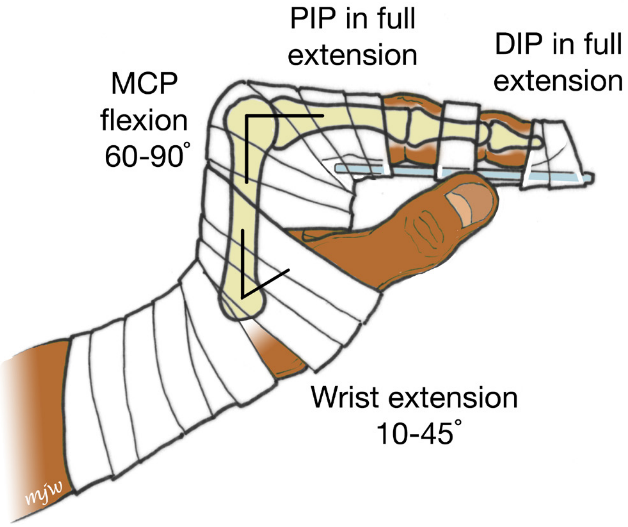
Ankle fractures may be immobilized with a well-padded splint or back slab, thereby decreasing pain while avoiding pressure over local bony prominences (■ **Figure 10-13**).

To temporarily splint the hand in a functional and anatomical position, the wrist should be slightly dorsiflexed and the fingers flexed at a 45-degree angle at the metacarpophalangeal joints (■ **Figure 10-14**). This is often achieved by placing the hand over a large roll of gauze and securing it with a short arm splint.

■ **Figure 10-13: Application of a Splint for an Ankle Fracture.** Illustrates the application of a splint for an ankle fracture using posterior and sugar-tong splints. **A.** Demonstrates the use of extensive padding around the lower extremity to ensure proper cushioning and prevent pressure injuries, with the posterior and sugar-tong plaster splints being secured in place using an elastic bandage. **B.** Shows the completed splint, which immobilizes the ankle and foot, maintaining stability to minimize movement and reduce the risk of further injury before definitive treatment. Proper padding and secure placement are crucial for effective splinting and patient comfort.



■ **Figure 10-14: Splinting a Hand Injury.** This figure shows the correct positioning for splinting a hand injury, including fractures and soft-tissue injuries. The wrist is placed in **10-45 degrees of extension** for optimal functional alignment. The **metacarpophalangeal (MCP) joints** are flexed at **60-90 degrees,** while the **proximal interphalangeal (PIP)** and **distal interphalangeal (DIP)** joints are kept in full extension. This positioning maintains the hand in a functional posture, reducing tension on ligaments and tendons, while minimizing joint stiffness and preventing deformity during the healing process. Proper padding and secure wrapping are essential to maintain this position and ensure comfort.

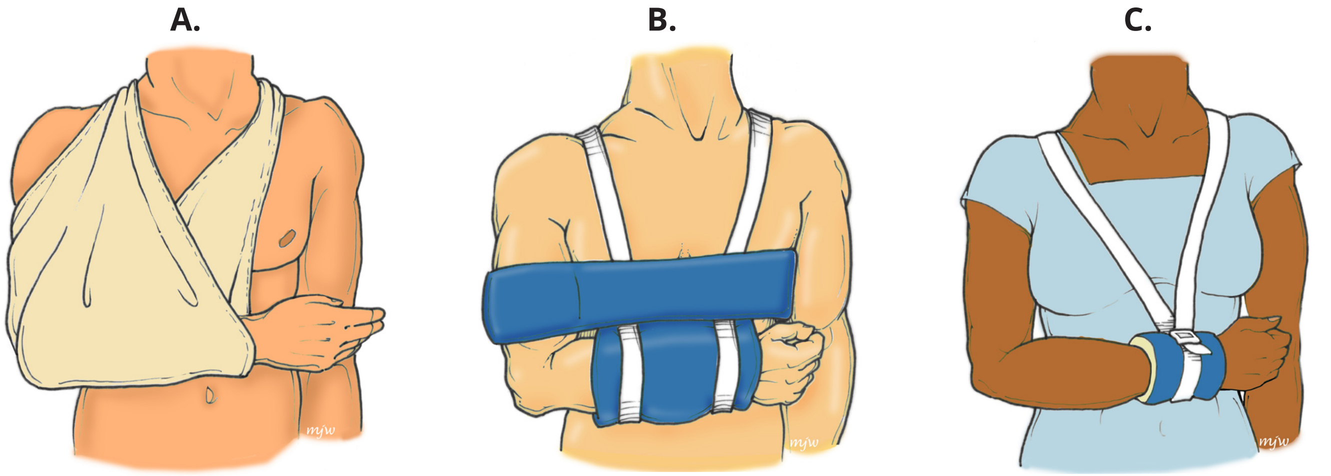


For immobilizing the forearm and wrist, flat padded or pillow splints are used to maintain a stable position. The elbow is usually kept in a flexed position using padded splints or immobilized close to the body with a pouch or a broad arm sling. Upper-arm stabilization can be achieved by splinting the arm to the body or using a sling or swath, potentially reinforced with a thoracobrachial bandage or a hanging plaster U-slab to ensure coronal alignment and provide axial support. Shoulder injuries are commonly managed with broad arm slings or collar-and-cuff devices to maintain a safe and effective position for healing (■ **Figure 10-15**).

X-RAY EXAMINATION

While x-ray imaging for skeletal injuries is typically part of the secondary survey, it may be necessary during the primary survey if fractures are suspected to contribute to shock. The choice and timing of x-rays should be guided by initial clinical observations, the patient's hemodynamic stability, and the injury mechanism. In the context of significant trauma, chest and anteroposterior (AP) pelvic x-rays are commonly indicated, yet their utility and optimal timing hinge on the patient's current condition and clinical presentation.

■ Figure 10-15: Immobilizing a Shoulder Injury. A. This figure depicts the proper use of a sling for immobilizing a shoulder injury. The sling supports the forearm and helps to stabilize the shoulder, reducing movement and providing comfort for conditions such as shoulder dislocations, fractures, or soft-tissue injuries. Proper fitting of the sling is crucial to ensure the elbow is supported at a right angle and that the hand is slightly elevated to minimize swelling. This immobilization technique is effective in initial management while awaiting further evaluation and definitive treatment. **B.** This figure demonstrates the application of a sling and swathe for immobilization of a shoulder injury. The sling supports the arm, while the swathe secures the arm to the chest, limiting shoulder movement and providing additional stability. This immobilization technique is particularly useful for managing shoulder dislocations, clavicle fractures, and proximal humerus fractures by reducing pain and preventing further injury during transport and initial treatment. Proper application is key to ensure comfort and maintain effective immobilization. **C.** This figure shows the use of a "cuff and collar" sling, which is a simple and effective method for immobilizing shoulder injuries. The cuff supports the wrist, while the collar loop secures the arm close to the body, providing stabilization and allowing the shoulder to rest in a comfortable position. This technique is particularly useful for shoulder dislocations, clavicle fractures, and proximal humerus injuries, minimizing movement and reducing pain.

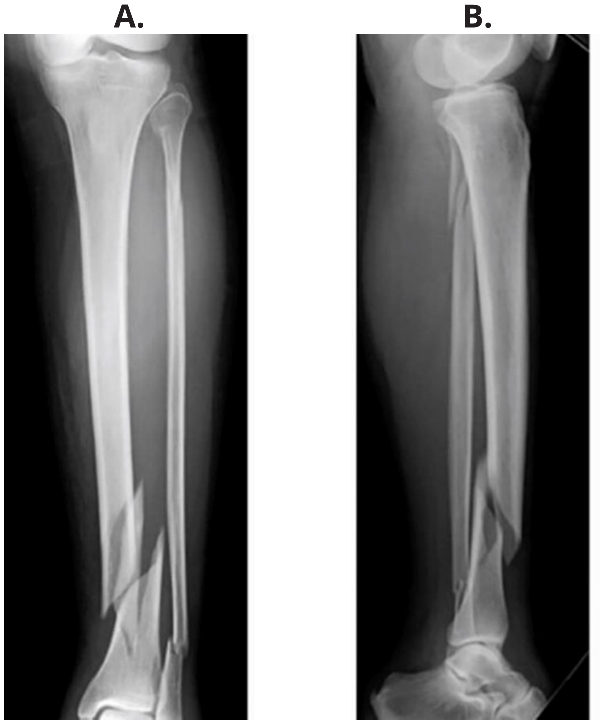


For musculoskeletal imaging beyond the chest and pelvis, it's crucial to adhere to orthopaedic imaging guidelines, which recommend capturing the entire bone in at least two orthogonal (perpendicular) views, including the joints above and below the injury site. This practice minimizes the risk of overlooking associated injuries (■ Figure 10-16).

An essential consideration is that x-rays or other imaging not directly relevant to immediate care should not be performed if they could delay more critical interventions. For instance, ankle x-rays are seldom justified in cases of potential airway compromise. However, when additional imaging does not detract from urgent care or delay treatment, it should be arranged so that all necessary images are obtained efficiently in one session, ensuring safety and minimizing disruptions.

The clinical examination of patients with musculoskeletal injuries frequently necessitates x-ray imaging to confirm diagnoses. Signs such as tenderness at a bone site, especially when accompanied by visible deformity, strongly suggest a fracture. X-rays should be obtained for hemodynamically stable patients, provided that the imaging does not interfere with more urgent care priorities. Symptoms like joint effusion, unusual tenderness around a joint, and joint deformity often point to joint injuries or dislocations, which also warrant x-ray evaluation.

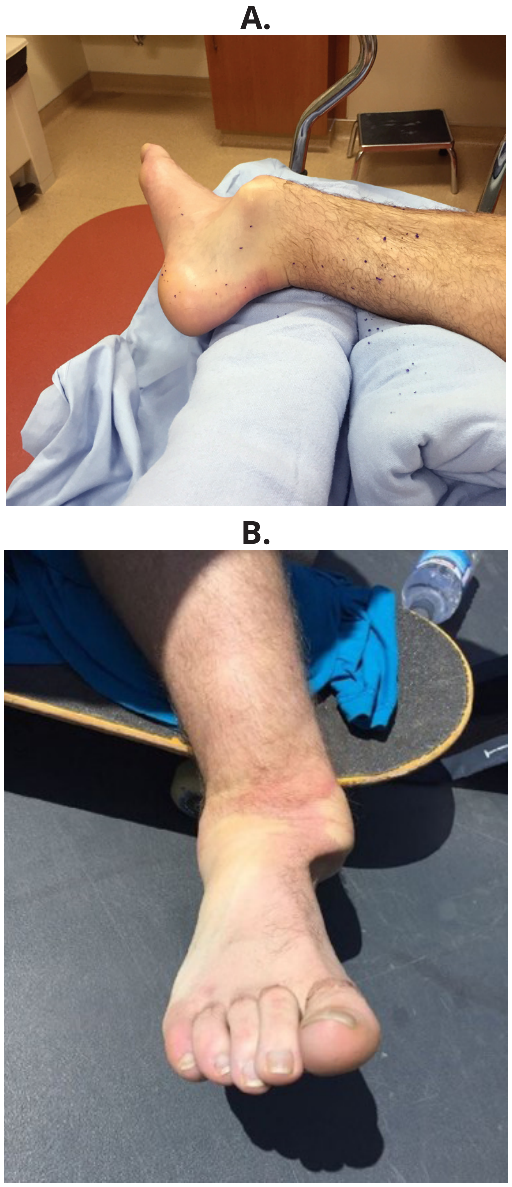
■ Figure 10-16: Radiograph of the Lower Extremity.
A. Radiograph of the lower extremity that includes the knee and ankle joint, the joint above and the joint below the comminuted distal tibia and fibula fracture.
B. Perpendicular view of the same extremity including the joint above and below the level of the fracture.



However, immediate x-ray imaging may be deferred in cases where there is neurovascular compromise or a risk of skin breakdown, conditions often observed with fracture dislocations of the ankle. In situations where x-ray acquisition is delayed, prompt reduction or realignment of the affected limb is critical to restore arterial blood flow and alleviate pressure on the skin, with subsequent immobilization to maintain alignment until further assessment and treatment can be provided (■ **Figure 10-17**).

Radiation safety is paramount for everyone in the vicinity during x-ray procedures, so follow local protocols. Nonessential personnel should exit the area during x-ray acquisition, while those remaining should use protective measures like lead aprons or shields. Patient safety regarding radiation exposure also demands careful consideration, including limiting unnecessary images and employing proper beam collimation to minimize exposure.

■ **Figure 10-17: Dislocation of the Distal Ankle.** **A.** Note the lateral dislocation of the distal ankle. **B.** There is nonhemorrhagic vascular compromise and skin tenting. Blanched skin associated with fractures and dislocations will quickly lead to soft-tissue necrosis. Prompt reduction will prevent pressure necrosis of the tissue.



SECONDARY SURVEY

During the initial assessment of trauma patients, not all injuries are immediately apparent. Areas with dense muscle coverage or significant subcutaneous fat can hide occult injuries, making it challenging to detect fractures with minimal displacement or subtle ligamentous damage to joints. This difficulty is compounded if the patient is unable to respond or has multiple severe injuries that may distract from less obvious ones. It's not uncommon for some injuries to be identified hours or days later when the patient is mobilized. This underscores the importance of ongoing patient reassessment and continuous communication among the trauma care team to remain vigilant for potential hidden skeletal injuries.

The importance of thoroughly understanding the mechanism leading to an injury and the time elapsed from the incident to medical evaluation cannot be overstated. Gathering detailed information from various sources—including the patient, their family, emergency responders, and witnesses provide clinicians a comprehensive view of the event. This information should be meticulously documented as part of the patient's initial history. **Analyzing the injury's mechanism allows healthcare providers to predict both significant and minor musculoskeletal injuries that might not be immediately visible.** This involves mentally reconstructing the incident, considering the forces involved and the potential for associated injuries beyond the musculoskeletal system. By doing so, practitioners can more accurately assess the patient's condition and tailor their approach to treatment.

Understanding a patient's condition prior to an injury is crucial for tailoring the treatment plan and predicting the outcome. Gathering a comprehensive history, including the AMPLE information, is crucial and should be thoroughly documented. Beyond AMPLE, knowing the patient's usual level of physical activity, medication use (both prescribed and over-the-counter), alcohol and illicit drug use, emotional and mental health status, and history of musculoskeletal injuries can significantly inform and guide clinical decision-making. This holistic view of the patient's preinjury condition allows healthcare clinicians to consider all factors that might influence recovery and rehabilitation strategies, ensuring the care plan is as effective and personalized as possible.

Visual inspection of limbs should assess skin color, swelling, deformity, and malalignment. A comprehensive visual check from head to toe is crucial to spot major external bleeding. Pale or white extremities may indicate poor arterial flow, while swelling in major muscle areas could suggest crush injuries or compartment syndrome. Swelling or bruising around joints or on bones hints at musculoskeletal injuries, and visible limb deformities often signal severe injuries.

Inspecting the patient's entire body for lacerations and abrasions is essential, including areas not immediately visible, necessitating careful patient repositioning to uncover potential hidden wounds. Fractures associated with open wounds should be presumed open until evaluated by a surgeon.

Observation of spontaneous motor function in the extremities aids in identifying neurological or muscular impairments. In conscious patients, the absence of spontaneous movement can indicate dysfunction. Assessing active muscle and nerve function involves having the patient move major muscle groups and joints to ensure integrity.

Palpation helps determine skin sensation and identify tender areas indicating possible fractures or nerve injuries. Joint stability is assessed through clinical examination for abnormal joint motion or tenderness that may suggest ligamentous injury. Excessive pain might limit this assessment due to muscular guarding, necessitating reevaluation.

Circulatory assessment involves palpating distal pulses, as well as comparing perfusion and capillary refill across all extremities. In cases of hypotension, Doppler assessment may be used to evaluate vascular flow. Discrepancies in pulses, extremity coolness, or pallor could indicate arterial injuries, especially near open wounds or fractures.

Some dislocations may spontaneously reduce, hiding their severity until a thorough physical examination is conducted. These can be associated with significant arterial injuries and may manifest as ischemic limbs or rapidly expanding hematomas, indicating arterial damage.

PAIN CONTROL

Appropriately splinting fractures or injured joints is crucial for reducing a patient's discomfort by minimizing movement at the injury site. Should pain persist or recur despite splinting, it's important to reassess the limb, possibly removing the splint for further evaluation. Analgesics are recommended for managing pain associated with joint injuries and fractures. Notably, patients not exhibiting expected pain levels from significant fractures may have other injuries affecting sensory perception, such as intracranial or spinal cord injuries, or could be influenced by substances like alcohol or drugs.

Narcotics are often necessary for effective pain management, administered intravenously in small, titrated doses and readministered as needed. When using sedatives, especially for procedures like dislocation reductions in patients with isolated limb injuries, caution is advised due to the risk of respiratory arrest. Therefore, having resuscitative equipment, naloxone (Narcan), and flumazenil readily available is essential.

Regional nerve blocks can be effective for pain relief and may aid in the reduction of certain fractures. However, it's critical to document the distal neurovascular status before implementing a nerve block, particularly to identify any preexisting peripheral nerve injuries. **In cases where acute compartment syndrome is a concern, the use of peripheral nerve blocks is contraindicated to avoid masking symptoms, making IV analgesics a safer choice.** This approach ensures pain management without compromising the ability to diagnosis or monitor for the development of potentially serious conditions like compartment syndrome.

TRANSFER TO DEFINITIVE CARE

When the musculoskeletal care needs of a patient surpass the capabilities available locally, prompt referral and planning for transfer are essential. Familiarity with local referral protocols is crucial to efficiently direct patients to suitable care. It's important to holistically assess the patient's immediate and long-term needs across all affected body systems, ensuring the chosen referral site has the necessary expertise and resources to address all aspects of care. For instance, a patient with femoral shaft fractures and late-stage pregnancy may require a facility that offers orthopaedic, obstetric, and neonatal services.

Upon deciding to transfer a patient, ensuring their stability for the journey is paramount, alongside arranging for necessary supports like splints, binders, and dressings to maintain immobilization and promote safe transit. Pressure points should be padded to prevent skin breakdown.

Transfer documentation must be clear and comprehensive, including the patient's neurovascular status, details of any peripheral ischemic events (e.g., tourniquet application times), interventions undertaken, and a list of confirmed or suspected injuries. While definitive diagnoses may not always be possible at the initial assessment stage, conveying the extent of documented or suspected injuries and any administered medications, including antibiotics and tetanus prophylaxis, is critical for continuity of care at the receiving facility. This approach ensures that the transition of care is smooth and that the receiving team is fully informed and prepared to continue appropriate treatment immediately.

PRACTICE ENVIRONMENT CONSIDERATIONS

Prefabricated splints and traction weights may not be readily available. Pieces of wood, string, cloth, bags, or bottles filled with fluid and rocks can be creatively assembled to create traction devices and splints. Pillows, blankets, and towels may be used instead of foam or cotton wool for padding when those options are not available. Prioritize needed imaging in cases of limited availability. Limb salvage may not be an option in areas where operative resources and transfer capabilities don't exist.

SPECIAL POPULATIONS

The energy required to cause a fracture in an older, frail patient may be trivial. Fractures can be difficult to identify on plain x-rays in these patients. In pediatrics, fracture patterns and implausible mechanisms of injury can lead to the suspicion of child abuse.

CHAPTER SUMMARY

Musculoskeletal injury is common in trauma patients. These injuries can threaten both life and limb. During the primary survey, recognize life-threatening bleeding resulting from extremity trauma and initiate the steps to control hemorrhage and resuscitate the patient. Fracture reduction and stabilization can aid in limiting blood loss from extremities and limb-threatening ischemia caused by fracture malalignment. A host of injuries can threaten loss of the injured limb if not identified and treated in a timely manner. Careful evaluation can identify patients at risk.

TIPS

- Initial care practitioners should be cognizant that a nonbleeding vascular injury in an extremity does not take clinical priority over exsanguinating hemorrhage or other higher-priority clinical concerns (i.e., immediate and potential life threats) in the Initial Assessment and treatment of a severely injured trauma patient. These injuries represent a potential ischemic limb threat and are appropriately managed and triaged as an important but often lesser care priority.

- The presence of a distal Doppler signal alone is often reassuring but does not exclude a significant arterial injury. A rapidly expanding pulsatile hematoma, absent distal pulse, or obvious external arterial bleeding are definitive signs of arterial injury.
- A deformed limb with distal circulatory compromise mandates traction, realignment, splinting, and neurovascular reevaluation, as this may be sufficient to restore perfusion. Always assess and document the distal neurovascular status of an extremity before and after any intervention or treatment.
- Where clinically appropriate and in keeping with local conventions, obtain clinical photographs of traumatic wounds/injuries.
- The diagnosis of acute compartment syndrome may be more challenging in patients with spinal cord injury, traumatic brain injury, altered mental status from medication or intoxication, or other injuries that may alter their perception of pain.
- Avoid peripheral nerve blocks in patients at risk for compartment syndrome.
- Contusions may evolve over time despite initially appearing innocuous.
- X-rays or other imaging should not interfere with the resuscitation of a patient.

TEAMWORK

- Musculoskeletal injuries, especially open fractures, are often dramatic and can potentially distract team members from resuscitation priorities. The team leader must ensure that team members focus on life-threatening injuries first.
- It is critical to recognize that certain musculoskeletal and limb injuries associated with catastrophic hemorrhage may rightly represent a severely injured trauma patient's highest clinical management priority. Rapid control of potentially exsanguinating external bleeding should be promptly addressed.
- More than one team member may be required to apply a traction splint, and the team leader may direct other assistants or specialist team members (e.g., vascular and orthopaedic surgeons) to assist.
- The team must recognize actual or potential limb-threatening injuries and report these accurately to the team leader so that decisions can be made for managing these injuries in conjunction with other identified life-threatening injuries.
- Ensure that the trauma team performs a complete, systematic, and thorough secondary survey so that injuries are not missed. Occult injuries are particularly common in patients with altered sensoria. The team leader should ensure timely reevaluation of the limbs to minimize missed injuries.

KEY LEARNING POINTS

- **Understanding the significance of musculoskeletal injuries: Learners should recognize that injuries involving the musculoskeletal system in major trauma scenarios can pose immediate potential threat to life and limb or lead to long-term disabilities.**
- **Mechanism of injury: It's crucial for learners to appreciate how the initial mechanism of injury can significantly influence the types and patterns of musculoskeletal injuries sustained, guiding the anticipation of additional injuries or possible complications.**
- **Identification of injury patterns: Learners should be able to recognize common musculoskeletal injuries or patterns that carry the risk of severe outcomes, including those that potentially threaten life or limb or could result in permanent disability.**
- **Initiation of appropriate treatment: Learners are expected to know how to begin proper treatment for musculoskeletal injuries during the primary survey of a trauma patient, especially in cases of severe bleeding.**
- **Use of musculoskeletal adjuncts: The ability to select and apply musculoskeletal adjuncts during the primary and secondary surveys is essential, based on the patient's clinical condition and the evolution of their injuries.**
- **Recognition of transfer needs: Understanding when a patient's care needs—immediate or anticipated—surpass the local facility's capabilities and necessitate transfer is critical.**

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11

Trauma in the Pediatric Patient

OBJECTIVES

After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Identify the unique characteristics of trauma in children, including common patterns and types of injuries, anatomic and physiologic differences from adult trauma, and long-term effects of injury
2. Discuss the primary management of trauma in children, along with the related issues unique to pediatric patients that affect resuscitation and explain the different equipment needs
3. Describe the injury patterns associated with child maltreatment and identify the factors that should raise a suspicion of child maltreatment
4. Emphasize the importance of injury prevention initiatives aimed at creating safer environments and activities for children

11

Trauma in the Pediatric Patient

CHAPTER STATEMENT

Pediatric trauma is a leading cause of morbidity and mortality in children, surpassing all other major childhood diseases. Each year, millions of children require emergency care for injuries, highlighting the critical need for pediatric readiness in trauma centers. The anatomical and physiological differences between children and adults necessitate specialized approaches to trauma assessment and management. Effective airway management, rapid volume resuscitation, and early surgical intervention are crucial to improving outcomes in severely injured pediatric patients. Understanding the common mechanisms of injury, including child maltreatment, is vital for clinicians to anticipate injury patterns and actual injuries. Ultimately, a multidisciplinary, team-based approach is essential for optimizing the care of injured children.

INTRODUCTION

Injury remains the most common cause of death and disability in childhood. Each year, more than 4.2 million children—nearly 1 of every 20 children—in the US require emergency department care for the treatment of injuries. In addition, more than 13,000 children and young adults (< 18 years) in the US die from serious injury each year. These include 7,800 unintentional injuries, 3,000 homicides, and 2,300 suicides. Injury morbidity and mortality surpass all significant diseases in children and young adults, making trauma the most serious public health and healthcare problem in this population.

Many of these injuries and fatalities are only addressable through prevention. But among injuries that reach medical care, failure to secure a compromised airway, support breathing, and recognize and respond to intra-abdominal and intracranial hemorrhage are the leading causes of unsuccessful resuscitation in pediatric patients with severe trauma. **In contrast to adults, failure to oxygenate and ventilate is the most common cause of preventable death after injury in children.** Therefore, pediatric readiness in emergency departments is critical to prevent unnecessary morbidity and mortality. By applying ATLS® principles to the care of injured children, trauma team members can significantly affect ultimate survival and long-term outcomes.

The priorities for assessing and managing pediatric trauma patients are the same as for adults. However, the pediatric population's unique anatomic and physiologic characteristics combine with the common mechanisms of injury to produce distinct injury patterns. For example, the most serious pediatric trauma is blunt trauma involving the brain. As a result, apnea, hypoventilation, and hypoxia secondary to traumatic brain injury occur far more frequently in children than hemorrhagic shock following trauma when compared to adults. Therefore, all treatment protocols for pediatric trauma patients emphasize aggressive management of airway and breathing.

TYPES AND PATTERNS OF INJURY

Around the world, motor vehicle-related crashes are the leading cause of death in children, whether they are occupants, pedestrians, or cyclists. In the US, firearm injuries are now the leading cause of death in children and young adults, followed by motor vehicle collisions. Deaths due to drowning, house fires, homicides, and falls follow in descending order. Child maltreatment accounts for the great majority of homicides in infants (i.e., children younger than 12 months of age). In contrast, firearm injuries account for most of the homicides in children (over age 1) and adolescents. Falls are responsible for the majority of pediatric injuries but infrequently result in death.

Blunt mechanisms of injury coupled with children's unique physical characteristics frequently result in multisystem injuries. Clinicians should presume, therefore, that multiple organs are injured until proven otherwise. ■ **Table 11-1** outlines common mechanisms of injury and associated injury patterns in pediatric patients.

The condition of the majority of injured children will not deteriorate during treatment, and most injured children have no hemodynamic abnormalities. **However, the condition of some children with multisystem injuries will rapidly deteriorate, with the development of serious complications.** Therefore, early transfer of severely or multiply injured pediatric patients to a facility capable of treating children with multisystem injuries is optimal.

GENERAL CONSIDERATIONS

Pediatric trauma patients have unique characteristics and equipment needs that are much different than those of the adult trauma patient.

SIZE, SHAPE, AND SURFACE AREA

Because children have smaller body mass than adults, the energy transmitted from objects such as fenders and bumpers or from falls results in greater force being applied per unit of body area. This concentrated energy is transmitted to a body with less fat, less connective tissue, and closer proximity to multiple organs than in an adult body. These factors result in the high frequency of multiple injuries seen in the pediatric population. In addition, a child's head is proportionately larger than an adult's, which results in a higher frequency of brain injuries from blunt trauma. Finally, due to the increased ratio of body surface area to body mass in young children, heat loss is a significant concern. **Hypothermia may develop quickly and complicate resuscitative efforts.**

■ Table 11-1: Common Mechanisms of Injury and Their Associated Injury Patterns in Pediatric Trauma.

Mechanism of Injury	Common Patterns of Injury
Pedestrian struck by motor vehicle	• **Low speed:** Lower-extremity fractures • **High speed:** Multiple trauma, head and neck injuries, lower-extremity fractures
Occupant in motor vehicle collision	• **Unrestrained:** Multiple trauma, head and neck injuries, scalp and facial lacerations • **Restrained:** Chest and abdominal injuries, lower spine fractures
Fall from a height	• **Low:** Upper-extremity fractures • **Medium:** Head and neck injuries, upper- and lower-extremity fractures • **High:** Multiple trauma, head and neck injuries, upper- and lower-extremity fractures
Fall from a bicycle	• **Without helmet:** Head and neck lacerations, scalp and facial lacerations, upper-extremity fractures • **With helmet:** Upper-extremity fractures • **Striking handlebar:** Internal abdominal injuries

SKELETON

A child's skeleton is incompletely calcified, contains multiple active growth centers, and is more pliable than an adult's. Therefore, fractures are less likely to occur in children, even when they have sustained internal organ damage. For example, rib fractures in children are uncommon, whereas pulmonary contusions are not. Other soft tissues of the thorax and mediastinum can sustain significant injury without evidence of bony injury or external trauma. The presence of skull or rib fractures in a child suggests the transfer of considerable energy; when they occur, underlying organ injuries, such as traumatic brain injury (TBI) and pulmonary contusion, should be highly suspected.

PSYCHOLOGICAL STATUS

The potential for significant psychological ramifications should be considered in children who experience trauma. Young children may demonstrate regressive psychological behavior when they experience stress, pain, or disruptions to their environment. Children have a limited ability to interact with unfamiliar individuals in unusual and stressful situations; this can lead to significant difficulty in taking a history and performing a physical exam.

When possible, clinicians should attempt to soothe an injured child and establish a good rapport, which, in turn, will facilitate a comprehensive assessment of the child's physical and psychological injuries. Additionally, the presence of parents or other caregivers during evaluation and treatment, including resuscitation, may help decrease the injured child's natural fears and anxieties.

LONG-TERM EFFECTS OF INJURY

A significant consideration in treating injured children is the effect of that injury on their subsequent growth and development. The potential physiologic and psychological effects of injury on this process can be significant, particularly in cases involving long-term function, cosmetics, and cognition. **Children who sustain even a minor injury may suffer prolonged physical and psychological disability.**

Some evidence suggests that as many as 60% of children who sustain severe multisystem trauma have residual personality changes one year after hospital discharge, and 50% show cognitive and physical impairments. Social, effective, and learning disabilities are present in one-half of seriously injured children. In addition, childhood injuries have a significant impact on family dynamics. Two-thirds of uninjured siblings also experience personality and emotional disturbances. Frequently, a child's injuries impose a strain on the parents' relationship, with possible financial and employment hardships. Trauma may affect not only the child's survival but also their quality of life for years to come.

One recently appreciated long-term effect of trauma stems from the widespread use of diagnostic ionizing radiation. Ionizing radiation may increase the risk of certain malignancies and should only be used if (1) the information needed cannot be obtained by other means; (2) the information gained will change the patient's clinical management; and (3) receiving the studies will not delay the transfer of a patient who requires a higher level of care. **The lowest possible radiation doses should be used if obtaining these studies.**

Ultimately, the long-term quality of life for children who have sustained trauma is surprisingly positive, even though, in many cases, they will experience lifelong physical challenges. Most patients report a good to excellent quality of life and find gainful employment as adults, an outcome justifying aggressive resuscitation attempts even for pediatric patients whose initial physiologic status might suggest otherwise.

EQUIPMENT

Successful assessment and treatment of injured children requires immediate access to appropriately sized equipment. A length-based resuscitation tape, such as the Broselow Pediatric Emergency Tape, is an ideal adjunct for rapidly estimating the patient's weight for appropriate fluid volumes, drug doses, and equipment size. One side of the tape lists drugs and their recommended doses for pediatric patients based on weight, and the other side identifies equipment needs for pediatric patients based on length. Clinicians should be familiar with length-based resuscitation tapes and their uses and ensure their practice location has appropriately sized equipment for patients of all ages. Several vendors offer smartphone applications designed to aid the clinician with weight- and size-based recommendations. (**■ Table 11-2**)

■ **Table 11-2: Pediatric Equipment Recommendations.** Successful assessment and management of injured children depends on the immediate availability of pediatric equipment of appropriate size.

Airway and Breathing

Age and weight	O_2 mask	Oral airway	Bag-valve	Laryngoscope	ET tube	Stylet	Suction
Preemie 3 kg	Preemie, newborn	Infant	Infant	0 straight	2.5–3.0 no cuff	6 Fr	6–8 Fr
0–6 mos 3.5 kg	Newborn	Infant, small	Infant	1 straight	3.0–3.5 no cuff	6 Fr	8 Fr
6–12 mos 7 kg	Pediatric	Small	Pediatric	1 straight	3.5–4.0 cuffed or uncuffed	6 Fr	8-10 Fr
1–3 yrs 10–12 kg	Pediatric	Small	Pediatric	1 straight	4.0–4.5 cuffed or uncuffed	6 Fr	10 Fr
4–7 yrs 16–18 kg	Pediatric	Medium	Pediatric	2 straight or curved	5.0–5.5 no cuff	14 Fr	14 Fr
8–10 yrs 24–30 kg	Adult	Medium, large	Pediatric, adult	2-3 straight or curved	5.5–6.5 cuffed	14 Fr	14 Fr

Circulation			Supplemental Equipment			
Age and weight	BP cuff	IV catheter[b]	OG/NG tube	Chest tube	Urinary catheter	Cervical collar
Preemie 3 kg	Preemie, newborn	22–24 ga	8 Fr	10-14 Fr	5 Fr feeding	—
0–6 mos 3.5 kg	Newborn, infant	22 ga	10 Fr	12-18 Fr	6 Fr or 5–8 Fr feeding	—
6–12 mos 7 kg	Infant, child	22 ga	12 Fr	14-20 Fr	8 Fr	Small
1–3 yrs 10–12 kg	Child	20-22 ga	12 Fr	14-24 Fr	10 Fr	Small
4–7 yrs 16–18 kg	Child	20 ga	12 Fr	20-28 Fr	10-12 Fr	Small
8–10 yrs 24–30 kg	Child, adult	18-20 ga	14 Fr	28-32 Fr	12 Fr	Medium

[a] Use of a length-based resuscitation tape, such as a Broselow™ Pediatric Emergency Tape, is preferred.
[b] Use of the largest IV catheter that can readily be inserted with reasonable certainty of success is preferred.
ET, Endotracheal; BP, Blood pressure; OG, Orogastric; NG, Nasogastric.

PEDIATRIC ANATOMIC CONSIDERATIONS

Clinicians caring for pediatric trauma patients must consider the following anatomic differences in children during primary survey and airway management:

- A proportionally larger occiput in infants and young children may result in neck flexion when supine, resulting in airway obstruction. If indicated, placing a layer of padding beneath the torso while maintaining cervical spine immobilization may help alleviate positional airway obstruction.
- A relatively large tongue in infants and young children may contribute to airway obstruction, especially in obtunded patients, and may be challenging to control and displace during direct laryngoscopy. An appropriately sized oropharyngeal airway (OPA) can hold the tongue anteriorly, maintaining airway patency during mask ventilation.
- Tonsillar hypertrophy is common in children and may complicate visualization during laryngoscopy.
- The larynx is more cephalad and anterior than in adults, creating a more acute angle between the base of the tongue and the glottis.
- **Children have a relatively large, floppy epiglottis, which may be easier to mobilize with a straight rather than curved laryngoscope blade.**
- The neonatal trachea is about 5 cm long and increases to about 12 cm in adults. A shorter trachea in children predispose to right mainstem intubation and endotracheal tube (ETT) displacement. A reasonable estimate for proper ETT depth from the gums (in centimeters) is three times the tube diameter when adequately sized.
- Historically, the pediatric larynx was thought to be funnel-shaped or conical. Newer studies suggest that this may not be accurate. The cricoid cartilage is elliptical in infants and younger children and grows to circular by adulthood.
- Increased resistance during endotracheal intubation (ETI) may be felt at the level of the elliptical cricoid, the space of which may be appropriately filled with a properly sized cuffed ETT. The American Heart Association has stated that it is reasonable to choose a cuffed ETT over uncuffed in infants and children, provided attention is paid to the size, location, and cuff pressure ($< 20–25$ cm H_2O).

PEDIATRIC AIRWAY EVALUATION, BASIC AIRWAY MANAGEMENT, AND ADJUNCTS

In pediatric trauma patients, after an immediate effort to control significant external hemorrhage, ensuring a patent airway is the next essential step in the primary survey. A patent airway is required to maintain oxygenation and ventilation and to prevent tissue hypoxia, secondary injury, and subsequent cardiac arrest.

In a spontaneously breathing child, assess the airway by looking for facial or neck injuries that may compromise the airway, listening to the quality of their voice and for any sounds suggestive of partial airway obstruction (gurgling, stridor, hoarseness), and listening to air movement and breath sounds. When partial airway obstruction is suspected, measures to optimize the airway include the following:

- Maintain cervical spinal motion restriction at all times when indicated
- Maintain the face and torso in the same plane, parallel to the stretcher
- Perform the jaw-thrust maneuver
- Head tilt should not be performed unless the cervical spine has been cleared or if the patient has a completely obstructed airway and cannot be ventilated with jaw thrust alone
- Suction should be readily available to clear the mouth of saliva, blood, secretions, or vomit
- Administer 100% oxygen

If the above measures result in a clear, maintainable airway, continue to monitor closely during resuscitation. If the airway is not clear or maintainable, preparations should be made to establish a definitive airway while assisting ventilation with 100% oxygen, if indicated. Preoxygenation before intubation has been shown in prehospital studies to be critical for achieving good patient outcomes.

Pediatric-size oral and nasal airways are available even for neonates. Nasal airways should not be used in trauma patients unless there is no concern for basilar skull fracture or facial trauma. An oropharyngeal airway (OPA) should not be used in awake patients, as it will likely induce vomiting. In an unconscious patient, an OPA may facilitate bag-mask ventilation while preparing for endotracheal intubation. The tip of a properly sized OPA should reach the angle of the mandible when held against the patient's cheek with the flange at the corner of the mouth. To minimize the risk of iatrogenic oral or tonsillar trauma, **do not insert the OPA upside down and rotate it into place**. Instead, while using a tongue depressor, gently insert the OPA in line with the curve of the oropharynx with direct visualization.

OROTRACHEAL INTUBATION

Indications for endotracheal intubation in pediatric trauma patients include but are not limited to the following:

- Inability to maintain a patent airway despite basic airway maneuvers
- Respiratory failure
- Altered mental status, which, in an acute trauma patient, can result from TBI, intoxication, hypoxia, or hypoperfusion from shock
- Injuries (especially burns) to the face, mouth, or neck, which may lead to complete airway obstruction once swelling has progressed

Selecting the proper size of the endotracheal tube (ETT) is essential and can be done by utilizing quick references such as a Pediatric Advanced Life Support Reference Card or length-based tape. **A simple technique to gauge the ETT size needed for a specific patient is to approximate the diameter of the child's external nares or the tip of the child's smallest finger and use a tube with a similar diameter.** Historically, uncuffed ETTs were recommended for infants and young children, because physiologic airway narrowing was felt to produce an adequate seal. More recently, cuffed tubes have been shown to improve capnography accuracy, reduce the need for ETT changes, and improve pressure and tidal volume delivery. Correctly sized cuffed

ETTs with proper inflation pressure (< 20–25 cm H_2O) have been shown to unlikely cause subglottic stenosis and generally safe to use in pediatric patients. Given these factors, in 2020, the American Heart Association stated that choosing a cuffed ETT for intubation in infants and children is reasonable. Ensure that ETTs one-half size larger and smaller than the selected tube, are available before intubation. If using a stylet to facilitate intubation, ensure that the tip does not extend beyond the end of the tube to avoid airway injury.

Most trauma centers use a protocol for emergency intubation, referred to as drug-assisted or drug-facilitated intubation, also known as rapid-sequence intubation (RSI). Clinicians must pay careful attention to the child's weight, vital signs (pulse and blood pressure), and level of consciousness to determine which branch of the algorithm for drug-assisted intubation to use (■ **Figure 11-1**).

■ Figure 11-1: Drug-Assisted Intubation in Pediatric Patients.

Preoxygenate

Atropine sulfate (infants only; less than 1 year)
0.1 - 0.5mg

Sedation

Hypovolemic	Normovolemic
Etomidate 0.1 mg/kg, or Midazolam HCl 0.1 mg/kg	Etomidate 0.3 mg/kg, or Midazolam 0.1 mg/kg

Paralysis*

Succinylcholine < 10 kg: 2 mg/kg > 10 kg: 1 mg/kg	or	Vecuronium 0.1 mg/kg	or	Rocuronium 0.6 mg/kg

Intubate, check tube position

*Proceed according to clinical judgment and skill/experience level.

Infants have a more pronounced vagal response to ETI than children and adults, and they may experience bradycardia with direct laryngeal stimulation. **Premedication with atropine** to prevent vagal-induced bradycardia should be considered in cases with a high risk of bradycardia, such as in infants or children younger than 8 years receiving succinylcholine. Atropine is dosed at 0.02 mg/kg with no minimum dose and a 1-mg maximum dose. There is a lack of evidence that premedication with lidocaine blunts the possible spike in intracranial pressure (ICP) during intubation.

In preparation for RSI, preoxygenate children with 100% oxygen via a nonrebreather or a bag-valve device if assisted ventilation is required. Consider placing a nasal cannula connected to oxygen on the patient to provide apneic oxygenation during RSI. Some studies have shown a longer interval to desaturation after paralysis in patients receiving apneic oxygenation compared to those who did not.

After sedation and paralysis, direct or video-assisted laryngoscopy should be performed to visualize the vocal cords for orotracheal tube placement. ETI should be performed by the most experienced clinician available, given the increased difficulty of intubating an infant or a young child. Before laryngoscopy, a trauma team member should maintain cervical spine immobilization while the front of the collar is removed to facilitate cricoid pressure, if needed.

Once the ETT is past the glottic opening, position it 2–3 cm below the level of the vocal cords and carefully hold it in place while intratracheal positioning is confirmed. A reasonable estimate for proper ETT depth from the gums (in centimeters) is three times the ETT tube diameter. Primary findings supportive of ETI include chest rise with assisted ventilation, mist in the ETT on exhalation, and auscultated breath sounds in the bilateral axilla and not over the stomach.

A secondary confirmation, using a device such as a real-time waveform capnograph, a colorimetric $ETCO_2$ detector, or an esophageal detector device should be used. $ETCO_2$ should be measured in patients receiving chest compressions and can predict the successful return of spontaneous circulation. Once ETI is confirmed, the tube should be properly secured, the cervical collar replaced, consideration given to the placement of an orogastric tube, and a chest x-ray should be obtained to accurately identify the ETT's position. If the tube is too high or too deep, adjust and resecure it before patient transport. Ensure that medications for sedation and pain control are utilized for the intubated child. Considerations include fentanyl, midazolam, and dexmedetomidine.

Generally, nasotracheal intubation in children is challenging and not recommended, as it requires blind passage around a relatively acute angle in the nasopharynx toward the anterosuperiorly located glottis. The potential for penetrating the child's cranial vault or damaging the more prominent nasopharyngeal (adenoidal) soft tissues and causing hemorrhage also discourages the use of the nasotracheal route for airway control.

If it is not possible to place the ETT after the child is chemically paralyzed, ventilate with 100% oxygen administered with a self-inflating bag-mask device until a definitive airway is secured. In the case of failed intubation, call for backup from the most experienced airway expert available. If subsequent attempts are unsuccessful, consider placing a supraglottic or surgical airway.

- Use the mnemonic DOPE to assess an intubated trauma patient who has an acute change in ventilatory status:
- Displacement—infants and young children have short tracheas; any movement of the head can result in migration of the tube out of the trachea or into a mainstem bronchus
- Obstruction—secretions, vomit or blood, may result in obstruction of the ETT and require inline suctioning
- Pneumothorax—positive-pressure ventilation may worsen a simple pneumothorax and lead to a tension pneumothorax that should be managed with decompression and tube thoracostomy
- Equipment—ensure tubing is appropriately connected, ventilator settings are correct, and the circuit is connected to oxygen

LARYNGEAL MASK AIRWAY AND CRICOTHYROIDOTOMY

When airway maintenance and control cannot be accomplished by bag-mask ventilation or orotracheal intubation, a rescue airway with either laryngeal mask airway (LMA), intubating LMA, or needle cricothyroidotomy is necessary. Needle-jet insufflation via the cricothyroid membrane is an appropriate temporizing technique for oxygenation, but it does not provide adequate ventilation, and progressive hypercarbia will occur. LMAs are appropriate adjunct airways for infants and children, but their placement requires experience, and ventilation may distend the patient's stomach if it is overly vigorous. **Surgical cricothyroidotomy should rarely be performed in infants or young children.** It can be performed in older children in whom the cricothyroid membrane is easily palpable (usually by age 12).

BREATHING

A critical factor in evaluating and managing breathing in pediatric trauma patients is the recognition of injuries that may result in compromised ventilatory effort, impaired gas exchange, and abnormal elimination of carbon dioxide. Compromised ventilatory effort may be caused by pneumothorax, hemothorax, and lung injury from contusion or aspiration. In such cases, appropriate treatments such as needle decompression, tube thoracostomy, and assisted ventilation should be pursued.

BREATHING AND VENTILATION

The respiratory rate in children decreases as they age. An infant breathes 30 to 40 times per minute, whereas an older child breathes 15 to 20 times per minute. Normal tidal volumes vary from 4–6 mL/kg for neonates to 6–8 mL/kg in infants and young children. However, tidal volumes as high as 10 mL/kg may be required during assisted ventilation. Although most bag-mask devices used with pediatric patients are designed to limit the pressure exerted manually on the child's airway, excessive volume or pressure during assisted ventilation substantially increases the potential for iatrogenic volutrauma and barotrauma. Similarly, when an adult bag-mask device is used to ventilate a pediatric patient, the risk of volutrauma and barotrauma is significantly increased. **A pediatric bag mask is recommended for children under 30 kg.**

Hypoxia is the most common cause of pediatric cardiac arrest. However, before cardiac arrest occurs, hypoventilation causes respiratory acidosis, which is the most common acid-base abnormality encountered during the resuscitation of injured children. A child should maintain a relatively normal pH with adequate ventilation and perfusion. In the absence of insufficient ventilation and perfusion, attempting to correct acidosis with sodium bicarbonate can result in further hypercarbia and worsening acidosis, and this practice should be discouraged.

NEEDLE AND TUBE THORACOSTOMY

Injuries that disrupt pleural apposition (i.e., hemothorax, pneumothorax, and hemopneumothorax) have similar physiologic consequences in children and adults. These injuries are managed with pleural decompression. In the case of tension pneumothorax, needle decompression should occur before chest tube placement. The needle should be inserted over the top of the third rib in the midclavicular line, or in the fifth intercostal space at the midaxillary line. Needle length and diameter must be optimized to ensure successful decompression while minimizing the risk of damage to underlying intercostal vessels and intrathoracic structures. Needles ranging from 16–22 gauge and 2.5–4.5 cm in length may be selected based on the child's age and body habitus.

Chest tubes need to be proportionally smaller and placed into the thoracic cavity by tunneling the tube over the rib above the skin incision site and directing it superiorly and posteriorly along the inside of the chest wall. The chest tube insertion site is the same in children as in adults: the fifth intercostal space, just anterior to the midaxillary line.

CIRCULATION AND SHOCK

Key factors in evaluating and managing circulation in pediatric trauma patients include recognizing circulatory compromise, accurately determining the patient's weight and circulatory volume, obtaining venous access, administering resuscitation fluids and blood replacement, assessing the adequacy of resuscitation, and achieving thermoregulation.

RECOGNITION OF CIRCULATORY COMPROMISE

Injuries in children can result in significant blood loss. A child's increased physiologic reserve allows for maintaining systolic blood pressure in the normal range even in shock. Up to a 30% decrease in circulating blood volume may be required to reduce the child's systolic blood pressure. A child's reserve can mislead clinicians who are not familiar with the subtle physiologic changes manifested by children in hypovolemic shock. **Tachycardia and poor skin perfusion are often the best keys to early recognition of hypovolemia and the need for early initiation of fluid resuscitation in children.** Evaluation of the fingernail bed color and color of the lips are helpful in all children, particularly children with deeply pigmented skin. When possible, early assessment by a surgeon is essential to the treatment of injured children.

Although a child's primary response to hypovolemia is tachycardia, an elevated heart rate also can be caused by pain, fear, or psychological stress. Other more subtle signs of blood loss in children include progressive weakening or loss of peripheral pulses, a narrowing of pulse pressure to less than 20 mm Hg, skin mottling (which substitutes for clammy skin in infants and young children), cool extremities compared with torso skin, and a decreased level of consciousness with a dulled response to pain. A decrease in blood pressure and other indices of inadequate organ perfusion, such as urinary output, should be monitored closely but generally develop later. Changes in vital organ function by degree of blood volume loss are outlined in ■ **Table 11-3**.

■ Table 11-3: Physiologic Effects of Blood Loss in Pediatric Patients.

System	Mild blood volume loss (< 30%)	Moderate blood volume loss (30%–45%)	Severe blood volume loss (> 45%)
Cardiovascular	Increased heart rate; weak, thready peripheral pulses; normal systolic blood pressure (80 − 90 + 2 × age in years); normal pulse pressure	Markedly increased heart rate; weak, thready central pulses; absent peripheral pulses; low normal systolic blood pressure (70 − 80 + 2 × age in years); narrowed pulse pressure	Tachycardia followed by bradycardia; very weak or absent central pulses; absent peripheral pulses; hypotension (<70 + 2 × age in years); narrowed pulse pressure (or undetectable diastolic blood pressure)
Central Nervous System	Anxious; irritable; confused	Lethargic; dulled response to pain[1]	Comatose
Skin	Cool, mottled; prolonged capillary refill	Cyanotic; markedly prolonged capillary refill	Pale and cold
Urine Output[2]	Low to very low	Minimal	None

[1] A child's dulled response to pain with moderate blood volume loss may indicate a decreased response to IV catheter insertion.
[2] Monitor urine output after initial decompression by urinary catheter. Low normal is 2 ml/kg/hr (infant), 1.5 ml/kg/hr (younger child), 1 ml/kg/hr (older child), and 0.5 ml/hg/hr (adolescent). IV contrast can falsely elevate urinary output.

The normal mean systolic blood pressure for children is 90 mm Hg plus twice the child's age in years (to a limit of 120 mm Hg). The lower limit of normal systolic blood pressure in children is 65 mm Hg plus twice the child's age in years. The diastolic pressure should be about two-thirds of the systolic blood pressure. Normal vital functions by age group are listed in ■ **Table 11-4**. Hypotension in a child represents a state of decompensated shock and indicates severe blood loss of greater than 45% of the circulating blood volume. Tachycardia changing to bradycardia often accompanies hypotension, and this change may occur suddenly in infants. Depending on what is available, these physiologic changes must be treated by a rapid infusion of 20 mL/kg of crystalloid or blood products.

DETERMINATION OF WEIGHT AND CIRCULATING BLOOD VOLUME

Emergency department personnel often struggle to estimate a child's weight, particularly when they do not frequently treat children. The simplest and quickest method of accurately determining a child's weight is to ask the parent or guardian. A length-based resuscitation tape is beneficial if a parent or guardian is unavailable. This tool rapidly provides the child's approximate weight, respiratory rate, fluid resuscitation volume, and drug dosages. The formula ([2 × age in years] + 10) is a final method for estimating weight in kilograms.

The goal of fluid resuscitation is to replace the circulating volume rapidly. Total circulating blood volume can be estimated as 80 mL/kg for an infant, 75 mL/kg at ages 1 to 3 years, and 70 mL/kg after age three.

VENOUS ACCESS

IV access in young children with hypovolemia can be challenging, even in the most experienced hands. The disruption of intrathoracic or intra-abdominal organs or blood vessels typically causes severe hypovolemic shock. A peripheral percutaneous route is preferable to establish venous access. **If percutaneous access is unsuccessful, consider placement of an intraosseous (IO) needle for infusion via bone marrow:** 18-gauge IO in infants, 15-gauge IO in young children (■ **Figure 11-2**), or a femoral venous line of appropriate size using the Seldinger technique. If these procedures fail, a physician with skill and expertise can perform direct venous cutdown. Still, this procedure should be used only as a last resort because it can rarely be performed in less than 10 minutes, even in experienced hands. In contrast, clinicians with limited skill and expertise can reliably place an IO needle in the bone marrow cavity in less than 1 minute.

The following are the preferred sites for venous access in children:

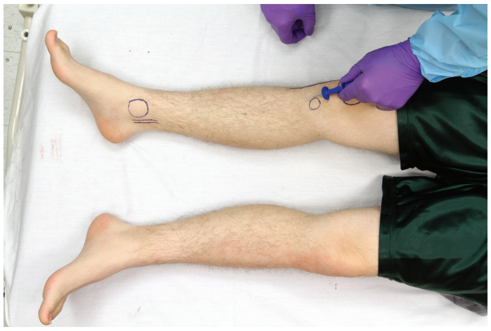
- Percutaneous peripheral IV—antecubital fossa or saphenous vein at the ankle
- IO placement—anteromedial tibia or distal femur. Complications of this procedure include cellulitis, osteomyelitis, compartment syndrome, and iatrogenic fracture. The preferred site for IO cannulation is the proximal tibia, below the level of the tibial tuberosity. An alternative site is the distal femur, although the contralateral proximal tibia is preferred. **IO cannulation should not be performed in an extremity with a known or suspected fracture or if a previous IO has failed in that bone.**
- Percutaneous central placement—femoral vein

■ **Table 11-4: Normal Vital Signs by Age Group.**

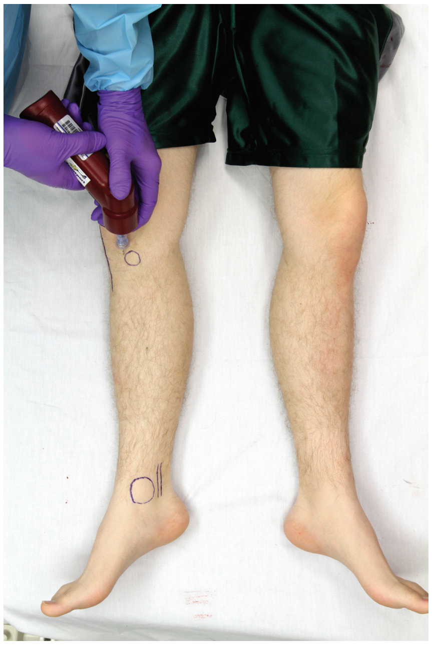
Age group	Weight range (in kg)	Heart rate (beats/min)	Blood pressure (mm Hg)	Respiratory rate (breaths/min)	Urinary output (mL/kg/hr)
Infant 0–12 months	0–10	<160	>60	<60	2.0
Toddler 1–2 years	10 - 14	<150	>70	<40	1.5
Preschool 3–5 years	14 - 18	<140	>75	<35	1.0
School age 6–12 years	18 - 36	<120	>80	<30	1.0
Adolescent ≥13 years	36 - 70	<100	>90	<30	0.5

■ **Figure 11-2: Intraosseous Needle Placement.** The preferred site for intraosseous cannulation and infusion is the anteromedial aspect of the proximal tibia, below the level of the tibial tuberosity.

View 1:



View 2:



- Percutaneous central placement—external or internal jugular or subclavian vein (should be reserved for pediatric experts; do not use if there is airway compromise or if a cervical collar is applied)
- Venous cutdown—saphenous vein at the ankle

FLUID RESUSCITATION AND BLOOD REPLACEMENT

Fluid resuscitation for injured children is weight-based, intending to replace any lost intravascular volume. Evidence of hemorrhage may be apparent with the loss of 25% of a child's circulating blood volume. The initial fluid resuscitation strategy for injured children is a 20 mL/kg bolus of crystalloid. If the patient does not demonstrate a sustained response to crystalloid, 10 mL/kg of packed red blood cells or whole blood should be given instead of additional crystalloid. However, **if hemorrhage is suspected and blood is immediately available, the resuscitation may be initiated with 10 mL/kg of packed red blood cells or whole blood instead of crystalloid.**

Damage control resuscitation, consisting of the restrictive use of crystalloids and early administration of balanced ratios of packed red blood cells, fresh frozen plasma, and platelets, has become standard in treating adult shock and has been adopted for children. This approach appears to interrupt the lethal triad of hypothermia, acidosis, and trauma-induced coagulopathy and has been associated with improved outcomes in severely injured adults.

Using balanced resuscitation strategies in children means the initial 20 mL/kg bolus of isotonic crystalloid is followed by weight-based blood product resuscitation with 10–20 mL/kg of packed red blood cells and 10–20 mL/kg of fresh frozen plasma and platelets, typically as part of a pediatric massive transfusion protocol (MTP). For facilities without ready access to blood products, slow infusion of crystalloid resuscitation remains acceptable until transfer to an appropriate facility is possible.

Carefully monitor injured children for response to fluid resuscitation and adequacy of organ perfusion. Children generally have one of four responses to fluid resuscitation:

1. The condition of most children will be stabilized by using crystalloid fluid only, and blood is not required; these children are considered "early responders."
2. Some children respond to crystalloid and blood resuscitation and are considered "responders." These are children who bled significantly but stopped bleeding before arrival.
3. Some children have an initial response to crystalloid fluid and blood, but then deterioration occurs; this group is termed "transient responders." These children are probably still bleeding.
4. Other children do not respond to crystalloid fluid and blood infusion; this group is called "nonresponders." These children are generally bleeding rapidly.

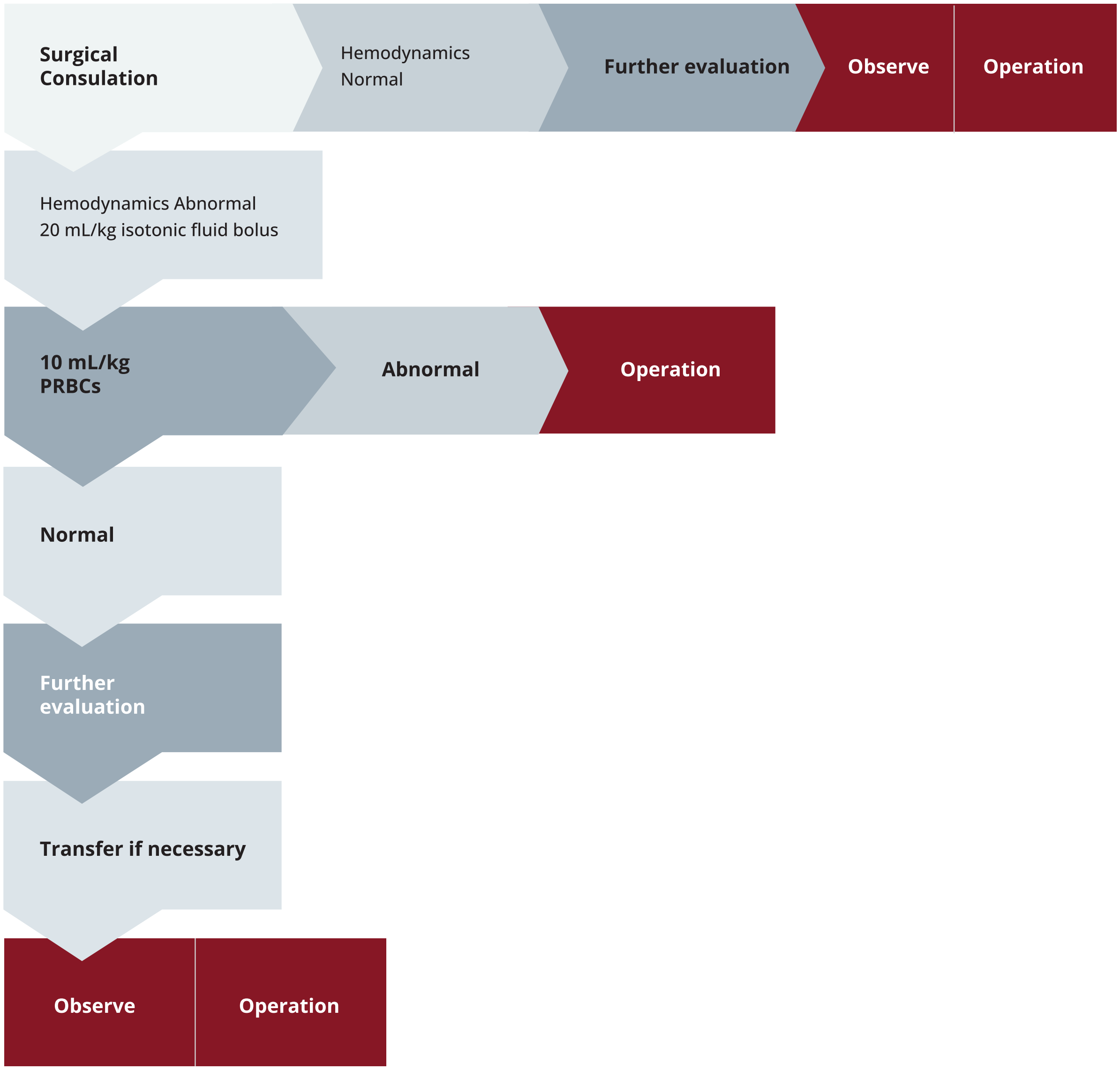
Transient responders and nonresponders are candidates for the prompt infusion of additional blood products, activation of an massive transfusion protocol (MTP), and consideration for early operation. Similar to adult resuscitation practices, earlier administration of blood products in refractory patients may be appropriate. The resuscitation flow diagram is valuable in treating injured children (■ **Figure 11-3**).

URINE OUTPUT

Urine output varies with age and size. The output goal for infants is 1–2 mL/kg/hr; for children over age one up to adolescence, the goal is 1–1.5 mL/kg/hr; and for teenagers, the goal is 0.5 mL/kg/hr.

Measurement of urine output and specific gravity is a reliable method of determining the adequacy of volume resuscitation. When the circulating blood volume has been restored, urinary output should return to normal. Inserting a urinary catheter facilitates accurate measurement of a child's urinary output.

■ **Figure 11-3: Resuscitation Flow Diagram for Pediatric Patients.**


Surgical Consulation
Hemodynamics Normal
Further evaluation
Observe
Operation
Hemodynamics Abnormal
20 mL/kg isotonic fluid bolus
10 mL/kg PRBCs
Abnormal
Operation
Normal
Further evaluation
Transfer if necessary
Observe
Operation

THERMOREGULATION

The high ratio of body surface area to body mass in children increases heat exchange with the environment and directly affects the body's ability to regulate core temperature. A child's increased metabolic rate, thin skin, and lack of substantial subcutaneous tissue also contribute to increased evaporative heat loss and caloric expenditure. Hypothermia can significantly compromise a child's response to treatment, prolong coagulation times, and adversely affect central nervous system (CNS) function. While the child is exposed during the initial survey and resuscitation phase, overhead heat lamps, heaters, and thermal blankets may be necessary to preserve body heat—warm the room, IV fluids, blood products, and inhaled gases. After examining the child during the initial assessment, cover the body with warm blankets to avoid unnecessary heat loss.

CARDIOPULMONARY RESUSCITATION

Children who undergo CPR in the field with a return of spontaneous circulation before arriving in the trauma center have an approximately 50% chance of neurologically intact survival. **Children who present to an emergency department still in traumatic cardiopulmonary arrest have a uniformly dismal prognosis.** Children who receive CPR for blunt trauma more than 15 minutes before arrival to an emergency department or have fixed and dilated pupils on arrival are uniformly nonsurvivors. For pediatric trauma patients who arrive in the trauma bay with continued CPR of long duration, prolonged resuscitative efforts are not beneficial. Data on CPR in the setting of penetrating chest trauma are consistent with the adult literature.

In the setting of patients found in cardiac arrest for an unknown period of time, early identification of lividity (a bluish-purple discoloration of the skin in dependent areas that sets in 20 to 30 minutes after death) or rigor mortis should immediately end resuscitative efforts.

CHEST TRAUMA

Eight percent of all injuries in children involve the chest. Chest injury also serves as a marker for other organ system injuries, as more than two-thirds of children with chest injuries have multiple injuries. The mechanism of injury and the anatomy of a child's chest are responsible for the spectrum of injuries seen.

The vast majority of chest injuries in childhood are due to blunt mechanisms, most commonly caused by motor vehicle crashes or falls. A child's chest wall's pliability, or compliance, allows kinetic energy to be transmitted to the underlying pulmonary parenchyma, causing a pulmonary contusion. Rib fractures and mediastinal injuries are not common; if present, they indicate a very severe impact. Specific injuries caused by thoracic trauma in children are similar to those encountered in adults, although the frequencies of these injuries differ.

The mobility of mediastinal structures makes children more susceptible to tension pneumothorax, the most common immediately life-threatening injury in children. Pneumomediastinum is rare and benign in the overwhelming majority of cases. Extensive workups for isolated pneumomediastinum in alert, asymptomatic children are not required. Diaphragmatic rupture, aortic transection, major tracheobronchial tears, flail chest, and cardiac contusions are also uncommon in pediatric trauma patients. When identified, treatment for these injuries is the same as for adults. Treatment may include endovascular aortic stent grafting if patient size allows. Significant injuries in children rarely occur in isolation and are frequently a component of significant multisystem injury.

Unlike in adult patients, most chest injuries in children can be identified with standard screening chest radiographs. Cross-sectional imaging is rarely required in the evaluation of blunt injuries to the chest in children and should be reserved for those with a widened or otherwise abnormal mediastinum on plain film or whose findings cannot be explained by standard radiographs. When pneumothoraces less than 2.7 cm are identified on cross-sectional imaging (occult pneumothorax), no intervention is required unless they are enlarging or symptomatic.

Most pediatric thoracic injuries can be successfully managed without thoracotomy. An appropriate combination of supportive care and tube thoracostomy will resolve the most common injuries, namely pneumothorax and hemothorax.

Penetrating trauma to the chest in children is managed the same way as for adults.

ABDOMINAL TRAUMA

Most pediatric abdominal injuries result from blunt trauma that primarily involves motor vehicles and falls. Serious intra-abdominal injuries warrant prompt involvement by a surgeon, and hypotensive children who sustain blunt or penetrating abdominal trauma require prompt intervention.

The presence of shoulder or lap-belt marks increases the likelihood of intra-abdominal injuries, especially in the presence of lumbar fracture, intraperitoneal fluid, or persistent tachycardia.

ASSESSMENT

Conscious infants and young children are generally frightened by traumatic events and the hospital environment, which can complicate the abdominal examination. Whenever possible, maintaining a child friendly environment is essential to calm the child, allowing for more accurate assessment and preventing further traumatic stress from hospitalization. Allowing the child's family to be with or near them and involving the child life team can help accomplish the goals of providing trauma-informed care to injured children. While talking quietly and calmly to the child, ask questions about the presence of abdominal pain and gently assess the tone of the abdominal musculature. One should avoid applying deep, painful palpation during the examination, which may cause voluntary guarding that can confuse the findings. As in adults, abdominal examination in unconscious children is unreliable.

Many infants and young children who are stressed and crying may swallow large amounts of air. **If the upper abdomen is distended on examination, insert an orogastric tube to decompress the stomach as part of the resuscitation phase.** Orogastric tube decompression is preferred in infants or if there is concern for basilar skull fracture.

Decompression of the urinary bladder may facilitate abdominal evaluation in these children but is usually reserved for those in whom hourly assessment of urine output is critical.

DIAGNOSTIC ADJUNCTS

Diagnostic adjuncts for assessing abdominal trauma in children include CT, FAST (focused assessment with sonography in trauma), and DPL (diagnostic peritoneal lavage).

COMPUTED TOMOGRAPHY

CT scanning allows for the rapid and precise identification of injuries. CT scanning is often used to evaluate the abdomen of children who have sustained blunt trauma and are hemodynamically stable or have shown a sustained response to fluid or blood. CT scanning should be immediately available and, when indicated, be performed early in treatment. Imaging should not delay definitive treatment in unstable patients. CT of the abdomen should routinely be performed with IV contrast agents according to local practice. Oral contrast is rarely needed and carries additional risks.

Identifying intra-abdominal injuries by CT in pediatric patients with hemodynamic stability can allow for nonoperative management by the surgeon. Early involvement of a surgeon is essential to establish a baseline that will determine if an operation is indicated. Centers that lack surgical support and where transfer of injured children is planned are justified in forgoing the CT evaluation before transport to definitive care.

CT scanning is generally rapid and can often be done without anesthesia or sedation, even in children. **When an injured child requires sedation to prevent movement during the scanning process, a clinician skilled in pediatric airway management and vascular access should accompany the child.**

CT scanning is not without risk. Radiation from CT scans in children is believed to contribute to subsequent malignancies. Fatal cancers are predicted to occur in as many as 1 in 1,000 patients who undergo CT as children. Thus, the need for accurate diagnosis of internal injury must be balanced against the risk of late malignancy. Avoid CT scanning before transfer to a definitive trauma center or a repeat CT upon arrival at a trauma center unless deemed absolutely necessary. When CT evaluation is essential, radiation must be kept as low as reasonably achievable. To achieve the lowest doses possible, scan only when medically necessary, scan only when the results change management, scan only the area of interest, and use the lowest radiation dose possible. Guidelines to determine who needs abdominal CT imaging have shown to reduce unnecessary CT scans of the abdomen.

FOCUSED ASSESSMENT SONOGRAPHY IN TRAUMA

FAST is widely used as an extension of the abdominal examination in injured children; it offers the advantage of being repeatable throughout resuscitation while avoiding ionizing radiation. Some investigators have shown that FAST identifies even small amounts of intra-abdominal blood in pediatric trauma patients, a finding that is unlikely to be associated with significant injury.

If large amounts of intra-abdominal blood are found, considerable injury is more likely to be present. However, even in these patients, operative management is indicated not by the amount of intraperitoneal blood but by hemodynamic abnormality and its response to treatment. FAST is incapable of identifying isolated intraparenchymal injuries, which account for up to one-third of solid organ injuries in children. Clinically significant intra-abdominal injuries may also be present in the absence of any free intraperitoneal fluid.

In summary, FAST should not be relied upon as the sole diagnostic test to rule out the presence of intra-abdominal injury. If a small amount of intra-abdominal fluid is found and the child is hemodynamically normal, a CT scan may be indicated. As in adults, the primary role of the FAST exam is to identify free fluid in the abdomen and pelvis in hemodynamically *unstable* children to determine if they would benefit from surgical exploration of the abdomen to achieve bleeding control.

DIAGNOSTIC PERITONEAL LAVAGE

DPL is rarely used in children. In rare circumstances, when ultrasound is NOT available and the presence of blood will lead to immediate operative intervention, it may be used to detect severe intra-abdominal bleeding in children who are hemodynamically unstable for unclear reasons and cannot be safely transported to the CT scanner. Blood found by DPL would not mandate operative exploration in an otherwise stable child.

NONOPERATIVE MANAGEMENT

Selective, nonoperative management of solid organ injuries in hemodynamically normal children is performed in most trauma centers, especially those with pediatric capabilities. The presence of intraperitoneal fluid (blood) on CT or FAST, the grade of injury, or the presence of a vascular blush does not necessarily mandate a laparotomy. Bleeding from an injured spleen, liver, or kidney generally is self-limited. Therefore, a CT or FAST that is positive for blood alone does not mandate a laparotomy in children who are hemodynamically normal or stabilized with resuscitation. **If the child's hemodynamic condition cannot be normalized and the diagnostic procedure performed shows ongoing bleeding, laparotomy is indicated for hemorrhage control.**

Children must be treated in a facility with pediatric intensive care capabilities, and nonoperative management must be supervised by a qualified surgeon. In resource-limited environments, thresholds to perform exploratory laparotomy may differ.

Angioembolization of solid organ injuries in children is a treatment option. Still, it should be performed only in centers with experience in pediatric interventional procedures and ready access to an operating room. The treating surgeon must decide to perform angioembolization. In contrast to adults, angioembolization in children with contrast blush on CT scans is only considered for hemodynamic instability or ongoing bleeding. Contrast extravasation or blush alone is not an indication for angioembolization in children.

Nonoperative management of confirmed solid organ injuries is a surgical decision made by surgeons, similar to the decision to operate. Therefore, the surgeon must supervise the nonoperative management of solid organ injuries in pediatric trauma patients.

SPECIFIC VISCERAL INJURIES

Several abdominal visceral injuries are more common in children than in adults. Injuries such as those caused by a bicycle handlebar, an elbow striking a child in the right upper quadrant, and lap-belt injuries are common and result when the visceral contents are forcibly compressed between the blow on the anterior abdominal wall and the spine posteriorly. This type of injury also may be also caused by child maltreatment.

Blunt pancreatic injuries occur from similar mechanisms, and their treatment depends on the extent of injury. Small bowel perforations at or near the ligament of Treitz are more common in children than in adults, as are mesenteric and small bowel avulsion injuries. These particular injuries are often diagnosed late because of their vague early symptoms.

Bladder rupture is also more common in children than in adults because of the shallow depth of the child's pelvis.

Children who are restrained by a lap belt only are at particular risk for enteric disruption, especially if they have a lap-belt mark on the abdominal wall or sustain a flexion-distraction (Chance) fracture of the lumbar spine. Any patient with this mechanism of injury and these findings should be presumed to have a high likelihood of injury to the gastrointestinal tract until proven otherwise. The rupture of a hollow viscus requires early operative intervention.

Penetrating injuries of the perineum (straddle injuries) may occur with falls onto a prominent object and result in intraperitoneal injuries due to the proximity of the peritoneum to the perineum.

HEAD TRAUMA

The information found in *Chapter 7, Disability: Neurological Assessment and Management*, also applies to pediatric patients. This section emphasizes information that is specific to children.

Most head injuries in the pediatric population are the result of motor vehicle crashes, child maltreatment, bicycle crashes, and falls. Since hypotension and hypoxia from associated injuries adversely affect the outcome of intracranial injury, lack of attention to the xABCDE algorithm and associated injuries can significantly increase mortality from head injury. As in adults, hypotension is infrequently caused by head injury alone, and other explanations for this finding should be investigated aggressively.

A child's brain is anatomically different from that of an adult. It doubles in size in the first 6 months of life and achieves 80% of the adult brain size by 2 years of age. The subarachnoid space is relatively smaller, offering less protection to the brain. Normal cerebral blood flow increases progressively to nearly twice that of adult levels by 5 years of age and then decreases. This increased cerebral blood supply accounts in part for children's significant susceptibility to cerebral hypoxia and hypercarbia.

ASSESSMENT

Children and adults can differ in their response to head trauma:

- **The outcome in children who suffer severe brain injury is better than that in adults.** However, for a similar injury, the outcome in children younger than 3 years of age is worse than in an older child. Children are particularly susceptible to the effects of secondary brain injury that can be produced by hypovolemia, hypoxia, seizures, or hyperthermia. The impact of the combination of hypovolemia and hypoxia on the injured brain is devastating, but hypotension from hypovolemia is the most severe single-risk factor. It is critical to avoid hypoxia and ensure rapid restoration of an appropriate circulating blood volume in injured children.
- Although infrequent, hypotension can occur in infants following significant blood loss into the subgaleal, intraventricular, or epidural spaces because of their open cranial sutures and fontanelles. In such cases, treatment should focus on appropriate volume restoration.
- Infants, with their open fontanelles and mobile cranial sutures, have more tolerance for an expanding intracranial mass lesion or brain swelling, and signs of these conditions may be hidden until rapid decompensation occurs. An infant who is not in a coma but has bulging fontanelles or suture diastases should be assumed to have suffered a severe injury, and early neurosurgical consultation is essential.
- Vomiting and amnesia are common after brain injury in children and do not necessarily imply increased ICP. However, persistent vomiting or vomiting that becomes more frequent is concerning and mandates a CT of the head.
- Impact seizures, or seizures that occur shortly after brain injury, are more common in children and are usually self-limited. All seizure activity requires investigation by CT of the head.
- Children tend to have fewer focal mass lesions than adults, but elevated ICP due to brain swelling is more common. Rapid restoration of normal circulating blood volume is critical to maintain cerebral perfusion pressure. If hypovolemia is not corrected promptly, secondary brain injury may occur. Emergent head CT is vital to identify children who require immediate surgery.
- The Glasgow Coma Scale (GCS) score is valuable in evaluating pediatric patients, but the verbal score component must be modified for children younger than 4 years (■ **Table 11-5**).

■ **Table 11-5: Verbal Score in Children Less than 4 Years of Age.** In children less than 4 years of age, the V-score component of the GCS must be modified to include an appropriate verbal response.

Verbal response	V-score
Appropriate words or social smile, fixes and follows	5
Cries, but consolable	4
Persistently irritable	3
Restless, agitated	2
None	1

- Because increased ICP frequently develops in children, neurosurgical consultation for consideration of ICP monitoring should be obtained early in the course of resuscitation for children with a GCS score of 8 or less, motor scores of 1 or 2, multiple associated injuries requiring significant volume resuscitation or immediate lifesaving thoracic or abdominal surgery, and a CT scan of the brain that demonstrates evidence of brain hemorrhage, cerebral swelling, and transtentorial or cerebellar herniation. Management of ICP is essential for optimizing the cerebral perfusion pressure.
- Medication dosages are determined by the child's size and in consultation with a neurosurgeon. Drugs often used in children with head injuries include 3% hypertonic saline and mannitol to reduce ICP, and levetiracetam and phenytoin for the treatment of seizures.

Criteria are available to identify patients at low risk for head, cervical spine, and abdominal injury who do not require CT scanning.

MANAGEMENT

Management of TBI in children involves rapid xABCDE assessment and management, as well as timely neurosurgical involvement from the beginning of resuscitation. Appropriate evaluation and management of the brain injury focused on preventing secondary brain injury—hypoxia and hypoperfusion—is also critical. Early endotracheal intubation with adequate oxygenation and ventilation can help avoid progressive central nervous system (CNS) damage. Attempts to orally intubate the trachea in an uncooperative child with a brain injury may be difficult and increase ICP. While considering the risks and benefits of intubating such children, pharmacologic sedation and neuromuscular blockade may facilitate the intubation.

Hypertonic saline and mannitol create hyperosmolality and increased sodium levels in the brain, decreasing edema and pressure within the injured cranial vault. These substances have the added benefit of being rheostatic agents that improve blood flow and downregulate the inflammatory response.

As with all trauma patients, continued reassessment of all clinical parameters remains essential. (Also *see Chapter 7, Disability: Neurological Assessment and Management.*)

SPINAL CORD INJURY

The information provided in *Chapter 7, Disability: Neurological Assessment and Management* also applies to pediatric patients. This section emphasizes information that is specific to pediatric spinal cord injury (SCI).

SCI in children is fortunately uncommon—only 5% of SCIs occur in the pediatric age group. For children younger than 10, motor vehicle crashes produce most of these injuries. For children aged 10 to 14 years, motor vehicles and sporting activities account for an equal number of spinal cord injuries.

ANATOMICAL DIFFERENCES

The following are anatomical differences that must be kept in mind when treating spinal injury in children:

- Interspinous ligaments and joint capsules are more flexible.
- Vertebral bodies are wedged anteriorly and tend to slide forward with flexion.
- The facet joints are flat.
- Children have relatively large heads compared with their necks. Therefore, the angular momentum is more significant, and the fulcrum exists higher in the cervical spine, which accounts for more injuries at the level of the occiput to C3.
- Growth plates are not closed, and growth centers are not entirely formed.
- Forces applied to the upper neck are relatively more significant than in the adult.

RADIOLOGICAL CONSIDERATIONS

Children sustain spinal cord injury without radiographic abnormalities more commonly than adults. A normal cervical spine series may be found in up to two-thirds of children who have suffered SCI. Thus, if SCI is clinically suspected, a normal spine x-ray does not exclude significant SCI. **Whenever in doubt about the integrity of the cervical spine, assume that an unstable injury exists, limit spinal motion, and obtain appropriate consultation.**

Another frequent unique radiologic finding in children is pseudosubluxation. Pseudosubluxation frequently complicates the radiographic evaluation of a child's cervical spine. Approximately 40% of children younger than 7 years show anterior displacement of C2 on C3, and 20% of children up to 16 years exhibit this phenomenon. This radiographic finding is seen less commonly at C3 on C4. Up to 3 mm of movement may be seen when these joints are studied by flexion and extension maneuvers.

When a subluxation is seen on a lateral cervical spine x-ray, ascertain whether it is a pseudosubluxation or an actual cervical spine injury. Pseudosubluxation of the cervical vertebrae is accentuated by the cervical spine flexion that occurs when a child lies supine on a hard surface. To correct this radiographic abnormality, ensure the child's head is in a neutral position by placing a 1-inch padding beneath the entire body from the shoulders to the hips (not the head) and repeat the x-ray. True subluxation will not disappear with this maneuver and mandates further evaluation. A cervical spine injury can usually be identified by neurological examination and by detecting an area of soft-tissue swelling, muscle spasm, or a step-off deformity on careful palpation of the posterior cervical spine.

An increased distance between the dens and the anterior arch of C1 occurs in approximately 20% of young children. Gaps exceeding the upper normal limit for the adult population are seen frequently.

Skeletal growth centers can resemble fractures. Basilar odontoid synchondrosis appears as a radiolucent area at the base of the dens, especially in children younger than 5 years. Apical odontoid epiphyses appear as separations on the odontoid x-ray and are usually seen between the ages of 5 and 11. The growth center of the spinous process can resemble fractures of the tip of the spinous process.

CT and MRI scans should not be used as routine screening modalities for evaluating the pediatric cervical spine; plain radiographs should be performed as the initial imaging tool. Indications for the use of CT or MRI scans include the inability to thoroughly evaluate the cervical spine with plain films, delineating abnormalities seen on plain films, abnormal neurologic findings on physical exam, and assessment of the spine in children with TBI; CT scan may not detect the ligamentous injuries that are more common in children.

SCI in children is treated in the same way as in adults. Consultation with a spine surgeon should be obtained early.

MUSCULOSKELETAL TRAUMA

Musculoskeletal injury is a common presenting complaint in pediatric patients, both isolated and associated with multisystem trauma. The initial priorities for managing skeletal trauma in children are similar to those for adults. Unique properties of the pediatric skeleton must be considered when evaluating and managing pediatric orthopaedic trauma.

HISTORY AND PHYSICAL

The patient's history and physical exam are vital in evaluating musculoskeletal trauma. In younger children, x-ray diagnosis of fractures and dislocations may be challenging due to the lack of mineralization around the epiphysis and the presence of the physis (growth plate). Information about the injury's magnitude, mechanism, and timing facilitates better correlation of the physical exam and x-ray findings. Administration of appropriate analgesia can facilitate examination and radiography.

Antibiotics should be administered promptly if there is concern for an open fracture. Any findings of neurovascular compromise or compartment syndrome should prompt emergent orthopaedic consultation or transfer to a higher level of care. Radiographic evidence of fractures in different stages of healing should alert clinicians to possible child maltreatment, as should lower-extremity fractures in children who are too young to walk.

BLOOD LOSS

Due to the thick periosteum around the pelvis, pediatric patients with pelvic fractures are much less likely to develop life-threatening intrapelvic hemorrhage compared to adults. Still, children with "open book" pelvic fractures and signs of shock should have a pelvic binder placed, be adequately resuscitated, and be transferred to a pediatric trauma center. Unlike adults, closed pediatric femur fractures are unlikely to result in enough hemorrhage to alter hemodynamics. **Therefore, hemodynamic instability in the presence of a presumed isolated femur fracture should prompt evaluation for other sources of blood loss, intra-abdominal being the most common.**

SPECIAL CONSIDERATIONS ABOUT THE IMMATURE SKELETON

The most clinically significant difference between the pediatric skeleton and the adult skeleton is the presence of the physis. As the location of growth and the weakest point of the bone, this cartilaginous area near the articular surface is more susceptible to fracture. Physeal fractures, best described by their Salter-Harris classification, require proper management and anatomic alignment to minimize the risk of deformity and growth disturbance. Crush injuries to the physis (Salter-Harris type V), are often challenging to recognize radiographically and have the worst prognosis. Pediatric bones are more porous and pliable than adult bones and have a thicker and more metabolically active periosteum.

While these differences result in faster healing and more significant remodeling potential, they also result in unique fracture patterns. Greenstick fractures are incomplete fractures that occur when the cortex is fractured on the side opposite of an impact, leaving an intact cortex and periosteum on the impact side. In small children, the torus, or "buckle," fracture involves angulation due to cortical impaction with a radiolucent fracture line.

A plastic deformity occurs when the bone is deformed beyond its ability to recoil with accentuated bowing, which indicates microscopic fractures not visible on x-rays. Supracondylar fractures at the elbow or knee have an increased risk of vascular injury, development of compartment syndrome, and physeal injury. **Due to the more elastic nature of the skeletally immature pelvis, even minimally displaced pelvis fractures should carry suspicion for high-energy mechanisms and associated cranial or abdominal visceral injuries must be ruled out.**

FRACTURE SPLINTING

Simple splinting of fractured extremities in children is usually sufficient until definitive pediatric orthopaedic management can be performed. Injured extremities with evidence of vascular compromise require emergency evaluation and treatment to prevent the adverse sequelae of ischemia. If emergent orthopaedic consultation is unavailable, a single attempt at a closed reduction to restore blood flow utilizing appropriate analgesia and sedation is appropriate, followed by immobilization of the extremity and timely transfer to a higher level of care. Hip dislocations require timely reduction to minimize the risk of avascular necrosis of the femoral head, which is increased with a delay of more than 6 hours. These reductions should be performed with appropriate sedation to avoid inadvertent physeal injury during reduction.

CHILD MALTREATMENT

Any child who sustains an intentional injury as the result of acts by caregivers is considered to be a battered or maltreated child. Homicide is the leading cause of intentional death in the first year of life. Children who suffer from physical abuse have a six-fold higher mortality rate than children who sustain unintentional injuries. Therefore, **a thorough history and careful evaluation of children in whom maltreatment is suspected is crucial to prevent eventual death,** especially in children who are younger than 2 years of age. Clinicians should suspect child maltreatment in the following situations:

- A discrepancy exists between the history and the degree of physical injury—for example, a young child loses consciousness or sustains significant injuries after falling from a bed or sofa or sustains a lower-extremity fracture even though they are too young to walk.
- A prolonged interval has passed between the time of the injury and the presentation for medical care.

- The history includes repeated trauma treated in the same or different emergency departments.
- The history of injury changes is different between parents or other caregivers.
- There is a history of hospital or doctor "shopping."
- Parents respond inappropriately to or do not comply with medical advice—for example, leaving a child unattended in the emergency facility.
- The mechanism of injury is implausible based on the child's developmental stage

The following findings, on careful physical examination, suggest child maltreatment and warrant more intensive investigation:

- Multiple bruises of different colors (i.e., bruises in different stages of healing)
- Evidence of frequent previous injuries, typified by old scars or healed fractures on x-ray examination
- Perioral injuries
- Injuries to the genital or perianal area
- Fractures of long bones in children younger than three years of age
- Ruptured internal viscera without antecedent major blunt trauma
- Multiple subdural hematomas, especially without a fresh skull fracture
- Retinal hemorrhages
- Bizarre injuries, such as bites, cigarette burns, and rope marks
- Sharply demarcated second- and third-degree burns
- Skull fractures or rib fractures seen in children less than 24 months of age

In many nations, clinicians are bound by law to report incidents of child maltreatment to governmental authorities, even in cases in which maltreatment is only suspected. Maltreated children are at increased risk for fatal injuries, so reporting is critically important. The system protects clinicians from legal liability for identifying confirmed or suspected maltreatment cases.

Although reporting procedures vary, they are most commonly handled through local social service agencies or state or national health services department. The process of reporting child maltreatment assumes greater importance when one realizes that 33% of maltreated children who die from assault in the US and the UK were victims of previous episodes of maltreatment.

PREVENTION

The greatest pitfall related to pediatric trauma is the failure to prevent the child's injuries in the first place. **Up to 80% of childhood injuries could be prevented by applying simple strategies of injury prevention in the homes and in the community** of a population among whom the lifetime benefits of successful injury prevention are self-evident. Not only can the social and familial disruption associated with childhood injury be avoided, but for every dollar invested in injury prevention, four dollars are saved in hospital care.

TEAMWORK

The care of severely injured children presents many challenges that require a coordinated team approach. Ideally, injured children are cared for by a pediatric trauma team composed of a physician with expertise in managing pediatric trauma, pediatric specialist physicians, and pediatric nurses and staff.

Team members should be assigned specific tasks and functions during the resuscitation to ensure an orderly delivery of care.

The reality is that most injured children will initially be treated in a facility with limited pediatric specialty resources. **An adult trauma team may be responsible for the care of injured children** and must be ready to provide the following:

- A trauma team leader who has experience in the care of injured patients and is familiar with the local medical resources available to care for injured children.
- A clinician with basic airway management skills.
- Access to a clinician with advanced pediatric airway skills.
- Ability to provide pediatric vascular access via percutaneous or IO routes.
- Knowledge of pediatric fluid resuscitation.
- Appropriate equipment sizes for a range of different ages.
- Strict attention to drug doses (weight-based).
- Early involvement of a surgeon with pediatric expertise, preferably a pediatric surgeon.
- Access to available pediatric resources (pediatrician, family medicine) to help manage pediatric-specific comorbidities or issues.
- Inclusion of the child's family during the emergency department resuscitation and throughout the child's hospital stay.
- Debriefing after a pediatric trauma case. Team members and others present in the resuscitation room may be deeply affected by poor outcomes for children. Appropriate mental health resources should be available.

CHAPTER SUMMARY

- Unique characteristics of children include significant differences in anatomy, body surface area, chest wall compliance, and skeletal maturity. Typical vital signs vary significantly with age. The xABCDE approach guides the initial assessment and management of severely injured children. Early involvement of a general surgeon or pediatric surgeon, preferably with expertise in trauma, is imperative in managing injuries in a child.
- **Pediatric emergency readiness is critical to prevent unnecessary morbidity and mortality in injured children, particularly in regard to airway management, which is the most important modifiable risk of death in injured children.**
- Nonoperative management of abdominal visceral injuries should be performed only by surgeons in facilities equipped to expeditiously handle any significant changes in the clinical course.

- Child maltreatment should be suspected if suggested by suspicious findings on history or physical examination. These include implausible history, delayed presentation, frequent prior injuries, injuries incompatible with developmental stage, and perineal injuries.
- Most childhood injuries are preventable. Doctors caring for injured children have a special responsibility to promote effective injury prevention practices within their hospitals and communities.

KEY LEARNING POINTS

- **Injury is the leading cause of death and disability in children, underscoring the importance of pediatric readiness in all emergency departments and trauma centers.**
- **Understanding the most common causes of pediatric injuries, such as motor vehicle accidents, falls, and child maltreatment, is helpful for the recognition of injury patterns.**
- **It is essential to consider the children's unique anatomical and physiological characteristics in the assessment and management of pediatric trauma.**
- **In contrast to adults, failure to oxygenate and ventilate is the most common cause of preventable death after injury in children.**
- **Tachycardia and poor skin perfusion are often the best keys to early recognition of hypovolemia and the need for early initiation of fluid resuscitation in children.**
- **Whenever in doubt about the integrity of the cervical spine, assume that an unstable injury exists, limit spinal motion, and obtain appropriate consultation.**
- **It is important to recognize potential cases of child maltreatment and understand the legal and ethical responsibilities for reporting suspected abuse.**
- **Up to 80% of childhood injuries could be prevented by applying simple strategies of injury prevention in the homes and in the community.**

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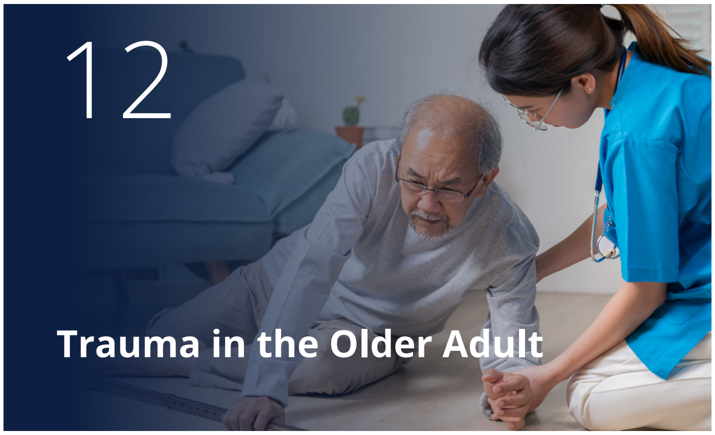
12

Trauma in the Older Adult

OBJECTIVES

After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Explain the physiological changes that occur with aging and how they affect the patient's response to injury
2. List the common mechanisms of geriatric trauma
3. Describe the effect of medications commonly prescribed to geriatric patients on injury physiology and response to resuscitation
4. Describe the signs of elder abuse and the significance of elder abuse to outcome in geriatric patients
5. Define ageism and how it can impact geriatric trauma care



12

Trauma in the Older Adult

CHAPTER STATEMENT

Geriatric patients represent an increasing demographic among injured patients. Low-energy mechanisms can produce substantial injury. The response of older adults to injury is influenced by preexisting injuries and frailty. Medications and organ dysfunction can alter the presentation of shock.

INTRODUCTION

Globally, the demographic shift toward an aging population is notable, with older adults becoming the fastest-growing age group. By 2050, it is projected that nearly half of the world's population will reside in countries where at least 20% are over 60 years old, with a quarter living in countries where older adults make up more than 30% of the populace.

This demographic shift represents a significant societal change in the 21st century, highlighted by the increased activity levels and longevity of today's older adults compared to previous generations. Access to high-quality healthcare in industrialized regions further enhances their quality of life. However, the active lifestyles and increased mobility of the current older adult population also expose them to a greater risk of sustaining serious injuries, making injury the fifth leading cause of death among this group.

The economic status of older adults affects their health, and the health of geriatric patients affects the economy. Older adults with lower incomes are more likely to have disabilities and die younger. For those with lower incomes, disability is likely to begin earlier in life, further increasing the risk of early mortality. The social determinants of health play a key role in the health trajectory of older adults. Older adults have greater healthcare and long-term care needs than younger people, leading to increased healthcare expenditures.

Managing geriatric trauma patients presents distinct challenges for trauma care teams. **The injury mechanisms in older adults differ, with falls being more prevalent, followed closely by motor vehicle and motorcycle crashes.** Inadequate triage of critically injured geriatric patients may contribute to their higher mortality rates compared to younger individuals. Beyond triage issues, the aging of organ systems, preexisting medical conditions, and frailty significantly elevate the mortality risk in older adults, underscoring that age alone cannot predict recovery potential. Mental health issues, substance abuse, and the risk of maltreatment are additional considerations.

Achieving the best outcomes for geriatric trauma patients demands a comprehensive, multidisciplinary approach focused on meticulous initial assessment, effective resuscitation, and continuous care. This strategy emphasizes the need for heightened vigilance and tailored interventions to address the unique vulnerabilities of the aging population in the trauma setting.

EFFECTS OF AGING

Aging is inherently associated with a decline in cellular function, leading to diminished organ performance. This decline is marked by a decrease in the body's ability to adapt and maintain homeostasis, resulting in a heightened vulnerability to injury-related stress, a phenomenon often referred to as "reduced physiological reserve" (■ **Table 12-1**). Consequently, injuries that younger individuals might easily recover from can have severe, sometimes catastrophic, outcomes in older adults.

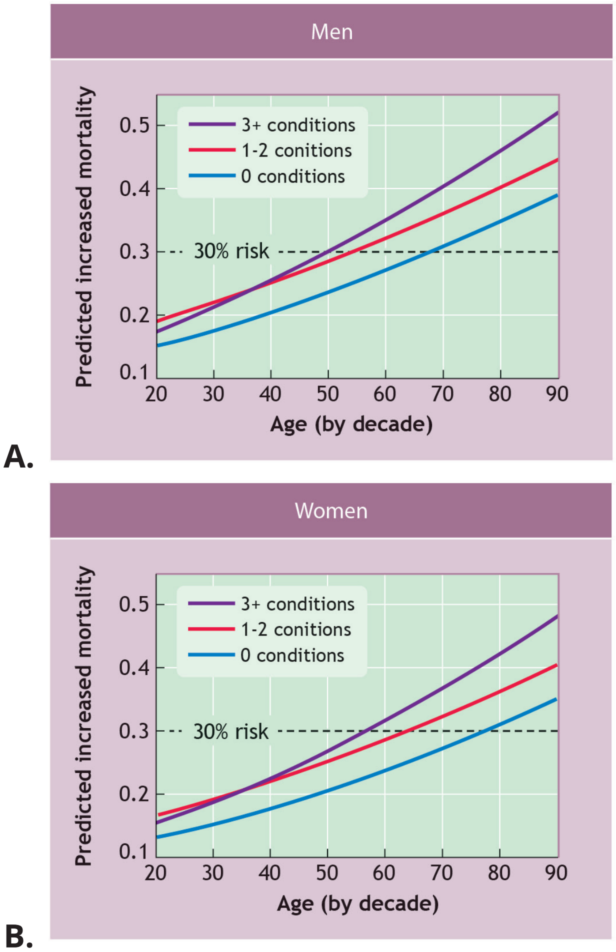
Research has documented the significant impact of preexisting conditions (PECs) on the morbidity and mortality outcomes of trauma patients. A notable study identified five critical PECs—cirrhosis, coagulopathy, chronic obstructive pulmonary disease, ischemic heart disease, and diabetes mellitus—that significantly influence trauma patient outcomes. In an analysis involving over 3,000 patients, it was found that one in four individuals aged 65 or older had at least one of these conditions. Furthermore, the presence of one or more of the critical PECs nearly doubled the mortality risk compared to patients without such conditions. **The study also highlighted the interplay between injury severity and host factors, including age, gender, and PECs, underscoring that while injury severity is a primary mortality determinant, host factors are also crucial** (■ **Figures 12-1A and B**).

■ **Table 12-1: Effects of Aging on Organ Systems and Implications for Care.**

Effects of Aging on Organ Systems and Implications for Care

Organ system	Functional changes	Implications for care
Cardiac	• Declining function • Decreased sensitivity to catecholamines • Decreased myocyte mass • Atherosclerosis of coronary vessels • Increased afterload • Fixed cardiac output • Fixed heart rate (β-blockers)	• Lack of "classic" response to hypovolemia • Risk for cardiac ischemia • Increased risk of dysrythmias • Elevated baseline blood pressure
Pulmonary	• Thoracic kyphoscoliosis • Decreased transverse thoracic diameter • Decreased elastic recoil • Reduced functional residual capacity • Decreased gas exchange • Decreased cough reflex • Decreased mucociliary function • Increased oropharyngeal colonization	• Increased risk for respiratory failure • Increased risk for pneumonia • Poor tolerance to rib fractures
Renal	• Loss of renal mass • Decreased glomerular filtration rate (GFR) • Decreased sensitivity to antidiuretic hormone (ADH) and aldosterone	• Routine renal labs will be normal (not reflective of dysfunction) • Drug dosing for renal insufficiency • Decreased ability to concentrate urine • Urine flow may be normal with hypovolemia • Increased risk for acute kidney injury
Skin/Soft Tissue/ Musculoskeletal	• Loss of lean body mass • Osteoporosis • Changes in joints and cartilages • Degenerative changes (including c-spine) • Loss of skin elastin and subcutaneous fat	• Increased risk for fractures • Decreased mobility • Difficulty for oral intubation • Risk of skin injury due to immobility • Increased risk for hypothermia • Challenges in rehabilitation
Endocrine	• Decreased production and response to thyroxin • Decreased dehydroepiandrosterone (DHEA)	• Occult hypothyroidism • Relative hypercortisone state • Increased risk of infection

■ Figure 12-1: Predicted Increased Mortality Risk in Older Adults. This figure illustrates the predicted increased mortality risk in older adults based on age and the number of preexisting medical conditions. Patients with multiple preexisting conditions have a significantly higher predicted risk of mortality.
A. Represents the mortality risk in men.
B. Represents the mortality risk in women.



Risk of Morality-Associated Geriatric Complications or Death, by Age and Number of Preexisting Conditions: Used with permission of Wolters Kluwer Health, Inc., from Min L, Burruss S, Morley E, et al. A simple clinical risk nomogram to predict mortality-associated geriatric complications in severely injured geriatric patients. *J Trauma Acute Care Surg.* 2013;74(4):1125-1132; permission conveyed through Copyright Clearance Center, Inc.

The concept of frailty in the older adult, characterized by a diminished response to physiological stress due to lower physiological reserve and multiorgan system insufficiency, has been recognized for decades and has more recently been applied to the trauma population. **The development of a Trauma-Specific Frailty Index** (**■ Figure 12-2**) **has enabled healthcare clinicians to identify patients at greater risk of poor outcomes and with increased resource needs.** Research indicates that targeted interventions for these frail geriatric patients can lead to improved outcomes, emphasizing the importance of a tailored approach in the management of geriatric trauma patients.

MECHANISM OF INJURY

Older adults are experience common mechanisms of injury such as motor vehicle crash (MVC), being struck as a pedestrian, burns, and penetrating injuries. Additionally—and somewhat unique to older adults—is the frequency of injury from ground-level falls, which can result in severe injury despite a seemingly trivial mechanism.

FALLS

The likelihood of experiencing a fall increase with age, and falls are the leading cause of fatal injury among older adults. Many factors heighten the risk of falls, including older age, physical limitations, a history of falls, the use of certain medications, dementia, balance issues, and gait instability, as well as visual, cognitive, and neurological impairments. Environmental hazards such as loose rugs, inadequate lighting, and slippery or irregular flooring also contribute significantly to the risk. Falls can also result from syncope or occult infection.

Despite the seemingly minor nature of ground-level falls, they can inflict severe, life-threatening injuries in older adults due to underlying frailty, osteoporosis, existing chronic conditions, and the use of certain medications such as anticoagulants. Traumatic brain injuries (TBI) stand out as a common injury from falls among older adults. Fifty-one percent of TBIs in older adults are caused by falls, while MVCs cause 9%. Additionally, falls leading to fractures, especially hip fractures, frequently result in a significant reduction of independence for nearly half of the geriatric patients affected.

MOTOR VEHICLE/MOTORCYCLE COLLISION

MVCs and motorcycle collisions (MCCs) rank as the second- and third-most common causes of injuries among older adults. Typically, older individuals drive fewer miles and at lower speeds compared to younger drivers. However, the risk of involvement in MVCs and MCCs for older drivers is increased by factors such as slower reaction times, increased size of blind spots, reduced neck mobility, diminished hearing, and cognitive decline. **Medical conditions like myocardial infarction, stroke, and dysrhythmias also contribute to scenarios that may lead to a collision.**

The types of physical injuries sustained in these collisions are like those observed in younger adults, but older adults face a higher risk of fractures, particularly in the upper cervical spine and ribs, largely due to osteoporosis. TBI in this population may be further complicated by the use of anticoagulants. Injuries may not be clinically obvious; therefore, liberal use of imaging for diagnosis is advised.

BURNS

Burn injury can be particularly devastating in geriatric patients. Although mortality rates from burns have decreased significantly in younger populations, the mortality risk from small to moderate burns remains disproportionately high among older adults. Research into deaths from structural fires highlights that older adults are especially vulnerable due to slower reaction times,

■ **Table 12-2: 15 Variable Trauma Specific Frailty Index.** This table presents the 15 Variable Trauma-Specific Frailty Index (TSFI), a tool used to assess frailty in older trauma patients. The TSFI includes factors related to comorbidities, daily activities, health attitudes, function, and nutrition, each assigned a score based on severity. The cumulative score, ranging from 0 to 15, provides an indication of a patient's frailty status, with a score greater than 0.25 suggesting frailty. Identifying frailty using the TSFI allows for risk stratification and aids in planning appropriate care for geriatric trauma patients.

15 Variable Trauma Specific Frailty Index (TSFI)							Total
Comorbidities	**Cancer History**	○ Yes +1		○ No +0			____
	Coronary Heart Disease	○ MI +1	○ CABG +0.75	○ PCI +0.5	○ Medication +0.25	○ None +0	____
	Dementia	○ Severe +1	○ Moderate +0.5	○ Milk +0.25	○ No +0		____
Daily Activities	**Help with grooming**	○ Yes +1		○ No +0			____
	Help with managing money	○ Yes +1		○ No +0			____
	Help doing housework	○ Yes +1		○ No +0			____
	Help toileting						____
	Help walking	○ Wheelchair +1	○ Walker +0.75	○ Cane +0.5	○ No +0.5		____
Health attitude	**Feel less useful**	○ Most time +1	○ Sometimes +0.5	○ Never +0			____
	Feel sad	○ Most time +1	○ Sometimes +0.5	○ Never +0			____
	Feel effort to do everything	○ Most time +1	○ Sometimes +0.5	○ Never +0			____
	Feel lonely	○ Most time +1	○ Sometimes +0.5	○ Never +0			____
	Falls	○ Within last month +1	○ Present not in last month +0.5	○ None +0			____
Function	**Sexually active**	○ Yes +0		○ No +1			____
Nutrition	**Albumin**	○ <3 g/dL +1		○ >3 g/dL +0			____
SCORE		**Frailty Index Score/15**		**>0.25 = Frail**			____

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diminished hearing and vision, and challenges in evacuating from a burning building. **Furthermore, incidents such as spills of hot liquids on the skin, which might result in superficial burns in younger individuals due to a higher density of hair follicles aiding in reepithelialization, often lead to full-thickness burns in older adults, who typically have fewer follicles.**

The decreased physiological reserve of aging organ systems plays a critical role in the recovery of geriatric burn patients. While the visible changes in the skin are apparent, it is the diminished capacity of geriatric patients to respond to the physiological demands of a burn injury that most significantly affects their outcomes and survival.

PENETRATING INJURY

By far, blunt trauma is the predominant mechanism of injury in older adults; however, a significant number of people over the age of 65 years are victims of penetrating injury. In fact, penetrating injury is the fourth-most common cause of traumatic death in individuals 65 years and older. Many deaths associated with gunshot wounds are related to intentional self-harm or suicide. The damage from the penetrating injury determines the initial mortality risk. For older adults who survive the initial injury, chronic comorbidities and baseline frailty are most influential in determining return to independence and mortality.

ELDER ABUSE

Annually, in the US, around 5 million older adults are subjected to elder abuse. The spectrum of abuse encompasses physical, sexual, and emotional harm, along with neglect, isolation, and financial exploitation, predominantly inflicted by family members (over 60% of cases). **The CDC defines "elder abuse" as any intentional act or failure to act that causes or risks harm to an older adult, typically by someone they trust. The manifestations include but are not limited to physical restraint, emotional distress, neglect by caregivers, abandonment, sexual abuse, and financial exploitation.** It is imperative for healthcare professionals to remain alert to the varied presentations and often subtle manifestations, from physical injuries to less apparent signs like poor hygiene or dehydration, indicators of neglect.

Elder abuse significantly increases mortality rates in older injured patients. Abused older adults have three times the mortality risk of those who are not abused. Discrepancies between a patient's and caregiver's accounts, along with physical findings or intentional delays in seeking treatment, should trigger reporting to relevant authorities for investigation. In cases of suspected or confirmed abuse, immediate measures should be taken to extricate the geriatric patient from the harmful environment.

The National Center on Elder Abuse reports that while over 10% of older adults may endure some form of abuse, less than 20% of these incidents are reported, underscoring the need for a comprehensive, multidisciplinary approach to care for elder abuse victims. Risk factors related to perpetrators of elder abuse are listed in ■ **Box 12-1**. Signs of the various types of elder abuse are listed in ■ **Box 12-2**.

■ **Box 12-1: Risk Factors Related to Perpetrators of Elder Abuse.**

Risk Factors Related to Perpetrators

- History of mental health problems or substance abuse
- History of medical problems
- Experience of traumatic life events or disruptive behavior
- High levels of stress
- Not prepared or trained to care for the elder
- Poor coping skills
- Experiencing or witnessing abuse as a child
- Social isolation
- Financial and emotional dependence on an elder

If in skilled nursing facility:

- Inadequate numbers or qualification of staff
- Staff stress or burnout

■ **Box 12-2: Signs of Elder Abuse.**

Signs of Elder Abuse

- Stops taking part in activities he or she enjoys
- Looks messy, with unwashed hair or dirty clothes
- Has trouble sleeping
- Loses weight for no reason
- Becomes withdrawn or acts agitated or violent
- Displays signs of emotional trauma, like rocking back and forth
- Has unexplained bruises, burns, cuts, or scars
- Has broken eyeglasses/frames
- Has physical signs of punishment or being restrained
- Develops bed sores or other preventable conditions
- Lacks medical aids (glasses, walker, dentures, hearing aid, medications)
- Has an eviction notice for unpaid rent, notice of late mortgage, or home eviction
- Has hazardous, unsafe, or unclean living conditions
- Displays signs of insufficient care or unpaid bills despite adequate financial resources

ASSESSMENT

PRIMARY SURVEY WITH RESUSCITATION

EXSANGUINATING EXTERNAL HEMORRHAGE

Management of uncontrolled external hemorrhage from lacerations or open wounds necessitates the application of pressure, packing, or the placement of a tourniquet. The removal of dressings should be approached with caution in geriatric patients due to the fragility of aged skin, which can exacerbate lacerations and tears. **Additionally, hematomas and contusions in this population have the potential to expand, contributing to significant blood loss. The diminished elasticity of tissues and the frequent calcification of blood vessels in older individuals can transform minor soft-tissue bleeding into extensive hematomas.** Furthermore, the common use of anticoagulant or antiplatelet medications among geriatric patients may exacerbate blood loss, necessitating careful consideration in the management of their injuries.

AIRWAY

Managing the airway in geriatric patients presents unique challenges. The significant reduction in protective airway reflexes among older adults necessitates quick and decisive action to establish a definitive airway, which can be critical for patient survival. Use of cervical collars in this population may heighten the risk of aspiration. Additionally, loose dentures can obstruct the airway; however, if they do not impede the airway, they should be left in place during bag-mask ventilation to enhance mask fit. The absence of teeth in some geriatric patients simplifies intubation but complicates bag-mask ventilation. Arthritis can restrict the ability to open the mouth and properly manage the cervical spine, potentially causing or worsening injuries.

During RSI, it is advisable to lower the doses of barbiturates, benzodiazepines, and other sedatives by 20% to 40% to reduce cardiovascular depression risk. It is crucial to consider these physiological changes and management strategies in airway assessment and management for older adults. Key physiological changes and management considerations of concern in airway assessment and management are listed in ■ **Table 12-3**.

■ **Table 12-3: Physiological Changes and Management Considerations of Older Adults.**

Physiological Changes and Management Considerations		
PRIMARY SURVEY	**Physiological Changes with Aging**	**Management Considerations**
AIRWAY	• Arthritic changes in mouth and cervical spine • Macroglossia • Decreased protective reflexes	• Edentulousness • Use appropriately sized laryngoscope and tubes • Place gauze between gums and cheek to achieve seal when using bag-mask ventilation • Ensure appropriate dosing of rapid-sequence intubation medications
BREATHING	• Increased kyphoscoliosis • Decreased functional residual capacity (FRC) • Decreased gas exchange • Decreased cough reflex • Decreased mucociliary clearance from airways	• Limited respiratory reserve; identify respiratory failure early • Manage rib fractures expeditiously • Ensure appropriate application of mechanical ventilation
CIRCULATION	• Preexisting cardiac disease or hypertension • Lack of a “classic response” to hypovolemia • Likelihood of cardiac medications	• Look for evidence of tissue hypoperfusion • Administer balanced resuscitation and blood transfusion early for obvious shock • Use advanced monitoring as necessary and on a timely basis
DISABILITY	• Cerebral atrophy • Degenerative spine disease • Presence of preexisting neurological or psychiatric disease	• Liberally use CT imaging to identify brain and spine injuries • Ensure early reversal of anticoagulant and/or antiplatelet therapy
EXPOSURE	• Loss of subcutaneous fat • Loss of skin elasticity • Arthritic skeletal changes • Nutritional deficiencies	• Perform early evaluation and liberate patients from spine boards and cervical collars as soon as possible • Pad bony prominences when needed • Prevent hypothermia

BREATHING

Aging leads to decreased compliance of the lungs and chest wall, which in turn increases the effort required for breathing. This physiological change, combined with a diminished respiratory reserve, significantly elevates the risk of respiratory failure in geriatric trauma patients. **Because aging causes a suppressed heart rate response to hypoxia, respiratory failure may present insidiously in older adults. Interpreting clinical and laboratory information can be difficult in the face of preexisting respiratory disease or nonpathological changes in ventilation associated with age**. Frequently, decisions to secure a patient's airway and provide mechanical ventilation may be made before fully appreciating underlying premorbid respiratory conditions. Key physiological changes and management considerations in assessing and managing breathing and ventilation are listed in ■ **Table 12-3**. Overall, these may lower the threshold for intubation.

CIRCULATION

Given the prevalence of hypertension among older adults, a blood pressure that appears normal may actually indicate a state of hypotension. Research supports using a systolic blood pressure threshold of 110 mm Hg to identify hypotension in those over 65. Older adults may not exhibit the typical compensatory tachycardia in response to hypovolemia due to factors like catecholamine insensitivity, atherosclerosis, myocyte fibrosis, or the use of certain heart medications, leading to a reliance on increased systemic vascular resistance. Early detection of significant tissue hypoperfusion is essential. Measures such as base deficit, serum lactate, and shock index are useful in detecting occult hypovolemia. Base deficit less than 6 or lactate greater than or equal to 2.4 may indicate occult hypovolemia. A shock index greater than or equal to 0.7 has 83% specificity for predicting the need for transfusion in patients over 65.

Resuscitation strategies for geriatric patients with hypoperfusion mirror those for younger patients, emphasizing balanced resuscitation with blood products and fluids as needed. Circulatory failure in geriatric trauma patients often suggests active bleeding. Early implementation of advanced monitoring techniques is recommended to navigate resuscitation effectively, especially considering the likelihood of underlying cardiovascular issues. Additionally, it is vital to consider that incidents like strokes, heart attacks, or dysrhythmias might have precipitated the trauma. Key physiological changes and management considerations in the assessment and management of circulation are listed in ■ **Table 12-3**. Procedures for placing monitoring lines in addition to other basic ATLS® procedures can be accompanied by an increase in complications in older adults, for which the clinician needs to be vigilant.

DISABILITY

TBI is a problem of epidemic proportion in the geriatric population. **With age, the cerebral atrophy results in more prominent subdural spaces. The bridging veins become fragile and may bleed following minor injury. Furthermore, the prevalent use of anticoagulant and antiplatelet medications among older adults for existing health conditions significantly increases their vulnerability to intracranial hemorrhages.**

Atherosclerosis, which is common in older age, can also play a role in either primary or secondary brain injuries. Due to the moderate cerebral atrophy often present in this age group, signs of intracranial injury may not be immediately apparent on neurological examinations. Additionally, cognitive, hearing, and visual impairments, as well as incongruent language use between patient and healthcare team, can lead to misleading Glasgow Coma Scale scores. Prompt recognition and management of these conditions, including the reversal of anticoagulant therapy, are crucial for improving outcomes in older adults following traumatic injuries. Key physiological changes and management considerations of concern in the assessment and management of disability are listed in ■ **Table 12-3**.

EXPOSURE AND ENVIRONMENT

Musculoskeletal changes associated with the aging process present unique concerns during this aspect of the initial assessment of the geriatric trauma patient. Loss of subcutaneous fat, nutritional deficiencies, chronic medical conditions, and preexisting medical therapies place older adult patients at risk for hypothermia and the complications of immobility (pressure injuries and delirium). Rapid evaluation and early liberation from spine boards and cervical collars, when possible, will minimize these complications. Key physiological changes and management considerations concerning exposure and environment are listed in ■ **Table 12-3**.

ADJUNCTS TO ASSESSMENT

Plain x-rays of the chest and pelvis in patients who have suffered blunt trauma will evaluate for pneumothorax, hemothorax, and fractures of the pelvis; eFAST (focused assessment with sonography in trauma) will evaluate for intra-abdominal fluid, pneumothorax, and pericardial effusion. Foreign body series are obtained for patients who have bullet injuries to localize any projectiles that remain; bullet wounds should be marked to allow determination of probable trajectories.

Laboratory assessment includes complete blood count, coagulation profile, comprehensive metabolic profile with hepatic panel, cardiac enzymes, toxicology panel for alcohol and drug screening, and arterial blood gas. Send urinalysis to evaluate for bleeding or potential occult infection. Thromboelastography is helpful in patients taking anticoagulants or who have evidence of active bleeding and can help guide resuscitation. Obtain an ECG. Acute ischemia or arrhythmia may underly the etiology of the trauma. Cardiac echocardiography may be useful when the injury is related to cardiac dysfunction. Determine whether naso-/orogastric or urinary catheter placement is needed.

REASSESSMENT

Repeat the primary survey, paying close attention to changes in vital signs. Obtain as much information as possible as possible about comorbid conditions, medications, and preinjury level of functioning. Reevaluate areas of bleeding or hematoma identified during the primary survey to determine whether bleeding is controlled or hematomas have enlarged. Perform a thorough secondary survey. Give antibiotics for open fractures and complex lacerations. Update tetanus immunization as needed.

ADJUNCTS

Occult injuries are common in this patient population. Whole body CT scan scan will be useful in identifying injuries that could otherwise be missed. It is particularly important in patients with unreliable examinations due to altered mental status from TBI, dementia, encephalopathy, or intoxication. Obtain plain x-rays of areas that may be fractured.

FRAILTY

At least one-third of older adults are frail. Frailty significantly influences outcomes in geriatric trauma patients, serving as a critical determinant of morbidity and mortality. This syndrome, characterized by decreased physiological reserve and increased vulnerability to stressors, results in a diminished ability to withstand trauma and leads to a higher likelihood of adverse outcomes, including prolonged hospitalization, increased need for institutional care, and a higher mortality rate. These patients are at risk for deterioration and mandate close observation.

GOALS OF CARE

Goals of care should reflect the patient's wishes and be consistent with their values. A goals-of-care discussion should take place when able. Advance directives, physician orders for life-sustaining treatment, or out-of-hospital do-not-resuscitate orders are also of importance in this population.

SPECIFIC INJURIES

Older and frail adults are subject to the same injuries from high-energy mechanisms as younger, nonfrail patients. However, there are specific injuries that are common in the older and frail population that may result from relatively minor or seemingly trivial mechanism of injury such as ground-level falls. These include rib fractures, TBI, cervical spinal cord and column injuries, and pelvic fractures.

RIB FRACTURES

Older and frail patients are at increased risk for rib fractures due to anatomical changes of the chest wall and loss of bone density. The most common cause of rib fractures is a ground-level fall, followed by MVC. The primary complication in geriatric patients with rib fractures is pneumonia, which can occur in susceptible lung parenchyma because of underlying pulmonary injury and/or inadequate ventilation from pain causing atelectasis.

In the older adult population, the incidence of pneumonia is reported to be as high as 30%. Mortality risk increases linearly with each additional rib fractured. The main objectives of treatment in patients with rib fractures are pain control and adequate pulmonary hygiene. Pain management can include oral medication, IV medications, transdermal medications, or regional anesthetics. Opioid administration in geriatric patients must be undertaken cautiously with close patient monitoring. Avoiding untoward effects, particularly respiratory depression and delirium, is of paramount importance. Multimodal therapy that minimizes the use of opioids is ideal. Regional analgesia with either epidural catheter, paravertebral catheter, or ultrasound-guided regional nerve blocks demonstrate a generally favorable profile and may allow reduced exposure to pain medications that can increase the risk of delirium.

The use of incentive spirometry to guide treatment is generally recommended. Admission to the ICU may be prudent in this high-risk population, and guidelines that stratify patients based on risk factors have demonstrated benefit and a reduction in complications.

TRAUMATIC BRAIN INJURY

Research shows that geriatric and frail patients are not only at an increased risk of suffering TBI but also suffer higher morbidity and mortality from this injury. Ground-level falls are a common cause, with an often subtle presentation and progression. Despite this vulnerability, specific guidelines for managing TBI in older patients are scarce. The evaluation process can be complicated by preexisting conditions such as delirium, dementia, or depression. Given the elevated risk of undetected intracranial bleeding, partly due to cerebral atrophy and chronic conditions, a liberal approach to CT scanning is advised, even when cognitive functions appear relatively intact.

The management of TBI in geriatric patients on anticoagulant or antiplatelet therapy poses additional challenges, given the higher incidence and mortality of brain injuries in this group. Early and aggressive reversal of anticoagulation may lead to better outcomes. ■ **Table 12-4** lists strategies for reversal of commonly used anticoagulants. In the older adult, reversal of anticoagulation using large volumes of fresh frozen plasma can lead to fluid overload. Using direct reversal agents or prothrombin complex concentrate, when available, allows for more efficient reversal with lower volumes of fluid. Unfortunately, morbidity and mortality in these cases are often exacerbated by preexisting conditions, and a tendency toward a pessimistic approach to treatment can further worsen outcomes. This underscores the importance of considering a patient's personal care goals when devising a treatment plan for severe TBI.

Notes:

- The choice of reversal strategy should consider the urgency of the situation, risk of thrombosis, and patient's comorbid conditions.
- Reversal agents like prothrombin complex concentrate (PCC) or Andexanet Alfa may carry risks of thromboembolic events and should be used cautiously.
- Close monitoring of coagulation status is crucial following reversal interventions.
- Use of fresh frozen plasma (FFP) for reversal may require administering large volumes which may not be tolerated in some older adults with congestive heart failure.

■ **Table 12-4: Medications and Strategies for Reversal of Commonly Used Anticoagulants in Older Adults.**

Medications and Strategies for Reversal of Commonly Used Anticoagulants in Older Adults

Anticoagulant	Reversal Agent/Strategy	Dosage	Comments
Warfarin (Coumadin)	Vitamin K, Fresh Frozen Plasma (FFP), Prothrombin Complex Concentrate (PCC)	Vitamin K: 5-10 mg IV; FFP: 10-15 mL/kg; PCC: 25-50 units/kg	Vitamin K for gradual reversal; PCC or FFP for urgent reversal
Unfractioned Heparin	Protamine Sulfate	1mg per 100 units of heparin (max 50 mg)	Dosage depends on the amount of heparin administered
Low-Molecular-Weight Heparin (e.g., Enoxaparin)	Protamine Sulfate (partial reversal)	1mg per 1mg of enoxaparin if given within 8 hours; 0.5 mg per 1mg if after 8 hours	Only partially effective; monitor anti-Xa levels if available
Direct Thrombin Inhibitors (e.g., Dabigatran)	Idarucizumab (Praxbind)	5 g IV (administered as two 2.5 g doses no more than 15 minutes apart)	Specific reversal agent for dabigatran; rapid onset of action
Factor Xa Inhibitors (e.g., Rivaroxaban, Apixaban)	Andexanet Alfa (Andexxa), Prothrombin Complex Concentrate (PCC)	Andexanet Alfa: 400-800 mg bolus followed by 4-8 mg/min infusion; PCC: 50 units/kg	Andexanet alfa for specific reversal; PCC for non-specific reversal
Fondaparinux	Recombinant Factor VIIa, Prothrombin Complex Concentrate (PCC)	rVIIa: 20-40 mcg/kg; PCC: 25-50 units/kg	No specific reversal agent; use PCC or rVIIa as off-label options
Antiplatelet Agents (e.g., Aspirin, Clopidogrel)	Platelet Transfusion, Desmopressin (DDAVP)	Platelet Transfusion: 1-2 units; Desmopressin: 0.3 mcg/kg IV	Desmopressin may enhance platelet function; platelet transfusion for critical bleeding

- **The choice of reversal strategy should consider the urgency of the situation, risk of thrombosis, and patient's comorbid conditions.**
- **Reversal agents like PCC or Andexanet Alfa may carry risks of thromboembolic events and should be used cautiously.**
- **Close monitoring of coagulation status is crucial following reversal interventions.**
- **Use of FFP for reversal may require administering large volumes which may not be tolerated in some older adults with congestive heart failure.**

CERVICAL SPINAL COLUMN AND SPINAL CORD INJURIES

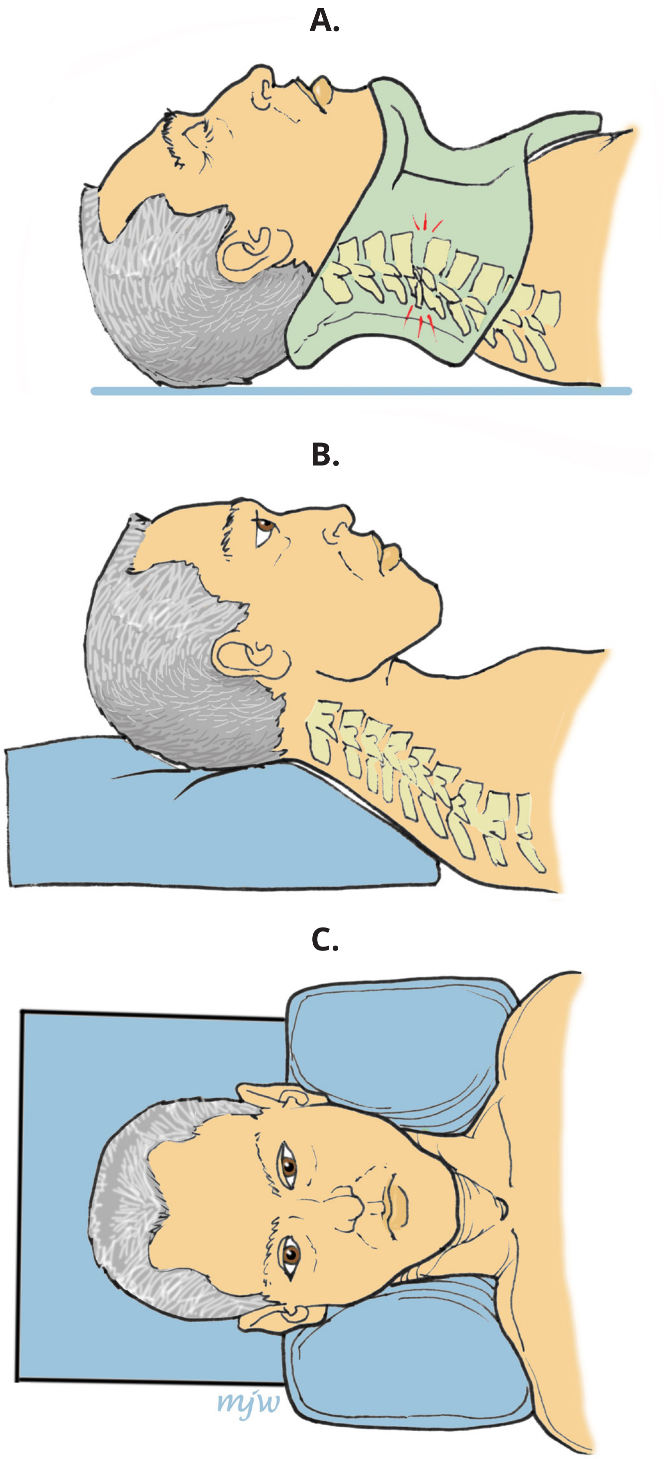
Older and frail patients are also at significant risk of both cervical spinal column injuries and spinal cord injuries. Osteoporosis and chronic degenerative changes of the spinal column make the cervical spine particularly susceptible to injury from falls. Classic mechanisms include hyperextension injuries from striking the front of the head. Odontoid fractures are exceptionally common and are associated with poor healing irrespective of the treatment chosen. Spinal motion restriction with a cervical collar is generally recommended but can lead to secondary problems including development of pressure sores, raised intracranial pressure, dysphagia, breathing difficulties, delirium, and compliance issues.

The presence of degenerative spinal diseases in older adults further heightens their risk of fractures and SCI, even from low-energy falls. In particular, ankylosing spondylitis can lead to severe injury and deficits in patients who suffer traumatic injury. Forcefully manipulating the neck to conform to the contour of a cervical collar can result in further injury. Instead, these patients should be positioned with sandbags or positioners supporting the occiput and either side of the head maintaining the fixed kyphosis (■ **Figure 12-2**). Cervical stenosis and degenerative disease of the cervical spine put the spinal cord at risk of compression injuries. Classically, central cord syndrome, in which the motor deficit of the upper extremities is greater than the lower extremities, can be seen in this patient population. Obtain neurosurgical consultation to determine the need for intervention.

PELVIC FRACTURES

Sarcopenia and osteopenia are frequently found in older and frail patients and can contribute to the development of pelvic fractures following relatively trivial energy-transfer mechanisms such as ground-level falls. **Mortality from pelvic fracture is four times higher in older patients than in a younger cohort. The need for blood transfusion, even in the absence of morphologies at increased risk of bleeding, is significantly higher than that seen in a younger population. Angioembolization may be required for bleeding control.** Older adults also have longer hospital stays and are less likely to return to an independent lifestyle following discharge due to issues with mobility. Fall prevention is the mainstay of reducing the mortality associated with pelvic fractures.

■ **Figure 12-2: A.** Patient with kyphosis and a cervical fracture with an ill-fitting cervical collar. Note forcing the abnormal anatomy into a cervical collar worsens the fracture anatomy. **B and C.** Patient with kyphosis and a cervical fracture with positioners supporting kyphosis improves alignment of cervical spine.



SPECIAL CIRCUMSTANCES

MEDICATIONS

Medication usage is highly prevalent among older adults, with 72% of individuals over 55 years old taking at least one prescription drug and 20% consuming four or more medications. While the management of chronic health conditions has benefited from these medications, it has concurrently led to an increase in polypharmacy. Classes of drugs such as antihypertensives, sedatives, hypnotics, neuroleptics, antipsychotics, antidepressants, and benzodiazepines are associated with an elevated fall risk in this demographic. The American Geriatrics Society publishes a list of potentially inappropriate medications for older adults (https://agsjournals.onlinelibrary.wiley.com/doi/epdf/10.1111/jgs.18372). Beta blockers, calcium channel blockers, and antiarrhythmics can affect hemodynamic responses to blood loss and to resuscitation. During the secondary survey of an older trauma patient, it is crucial to assess and document their medication regimen. Medications that particularly complicate the management of a bleeding patient include anticoagulants, antiplatelet agents, and direct thrombin inhibitors. Prompt identification of these medications and the administration of appropriate reversal agents may improve outcomes.

AGEISM

***Ageism* is commonly described as implicit or explicit bias against individuals based on their age**. Robert Neil Butler, first director of the National Institute on Aging, introduced the term in 1969 referring to discrimination against older individuals. Triggered by unfavorable and misleading stereotypes, ageism is deeply embedded in our culture and less commonly acknowledged than other types of prejudice and discrimination. In fact, younger patients are frequently given priority when allocating resources in traditional healthcare. According to one survey, one in five Americans over the age of 50 in the US report having experienced discrimination in healthcare settings, which can lead to improper or suboptimal care.

In the emergency room, older adults may be excluded from discussions and decision-making regarding their own care due to false assumptions of cognitive decline or dementia. Decreased vision and hearing may compromise their ability to communicate in the stressful and noisy setting of the trauma room. Presumption of comorbidities and ailing physiological functions due to advanced age may influence treating physicians' choice of diagnostic tests and limit resuscitation efforts due to an overstated concern of futility of care and expected inability to restore geriatric patients' functional status to preinjury levels.

Adopting an individualized, patient-centered treatment approach may help the trauma team mitigate ageism. Like other types of bias, recognizing its existence is the critical initial step. Reflecting on its causes and how it may influence clinician-patient interactions and treatment decisions can lead to behavioral modification, improved trauma care, and resource utilization.

TRANSFER CONSIDERATIONS

Geriatric trauma patients are frequently undertriaged. Subtle initial physiological changes and low-energy mechanisms combine to increase the probability of undertriage. Early identification of injuries with appropriate resuscitation gives these patients the best chance of good outcome. Patients with TBI, SCI, complex fractures, multiple rib fractures, and intra-abdominal injuries may require transfer to a trauma center for definitive care. These patients may also have comorbid conditions that affect their recovery from injury. After assessment and resuscitation, transfer can be initiated. *Chapter 15, Transfer to Definitive Care*, outlines considerations for safe patient transfer. Frail patients with severe injuries should receive care that aligns with their goals of care.

CHAPTER SUMMARY

Falls are the most common mechanism of injury for older adults. Seemingly trivial mechanisms can result in severe injury such as multiple rib fractures, TBI, spinal column fracture, and pelvic fracture. Preexisting health conditions and frailty have significant effects on morbidity and mortality. Shock can be masked by medications and PECs. Thorough assessment and resuscitation give the best chance for good outcome.

KEY LEARNING POINTS

- **Older adults are the fastest-growing segment of the population. Trauma clinicians will see an increasing number of injured older adults.**
- **Common mechanisms of injury include falls, MVCs, motorcycle collisions, burns, and penetrating injuries.**
- **The influence of changes in anatomy and physiology, frailty, and preexisting medical conditions adversely affects outcomes.**
- **Ageism may result in bias that should be recognized and addressed to optimize care.**
- **The primary survey sequence is the same as for younger adults. Physiologic changes associated with aging, comorbid conditions, and frailty may affect response to injury and resuscitation.**
- **Common injuries in older adults include rib fractures, TBI, spine injuries, and pelvic fractures. Understanding the impact of aging and its influence on pitfalls seen with these injuries and procedures will result in better outcomes.**
- **The impact of medications, elder abuse, and understanding the goals of care are particularly important features of trauma care of the geriatric patient. Early identification along with a team approach will influence care and outcomes.**

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13

Trauma in the Pregnant Patient

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Describe important anatomic and physiologic changes that occur in the later stages of pregnancy that may impact initial patient assessment and treatment in the setting of acute trauma
2. Outline the treatment priorities and assessment methods for a pregnant patient and their fetus during the primary and secondary surveys, including the use of adjuncts
3. Summarize the indications and technique for performing left-uterine displacement, including the physiologic benefit it creates in the pregnant trauma patient
4. Identify the appropriate timing to involve the obstetrics team, either in person or via remote consultation
5. Identify which pregnant trauma patients are at risk for placental abruption, including the appropriate timing to involve the obstetric team
6. Describe modifications to common interventions such as IV/IO access (above the diaphragm) and chest tube placement in the later stages of pregnancy
7. Recognize which pregnant trauma patients may require Rh immune globulin prophylaxis, and state the resources available for determining the dosage, route, and timing of administration
8. Describe the timing and indication for resuscitative cesarean delivery and the resulting beneficial physiologic changes to the pregnant patient
9. Identify common mechanisms of injury for a pregnant patient and their fetus, including possible intimate partner violence

13

Trauma in the Pregnant Patient

CHAPTER STATEMENT

Trauma is a significant contributor to morbidity and mortality during pregnancy. Clinicians caring for an injured pregnant patient must remember that the sequence of care is the same as for nonpregnant patients and that effective diagnosis, treatment, and resuscitation of the mother is the best way to achieve optimal outcomes for both her and the fetus. Clinicians must also remember that even "minor" mechanisms of injury can cause adverse outcomes.

INTRODUCTION

Trauma is a significant contributor to morbidity and mortality during pregnancy. One in 12 pregnancies are estimated to be complicated by trauma. In the US, trauma is the leading cause of nonobstetrical maternal death. In addition, trauma has a tremendous impact on fetal outcomes, including increased incidence of spontaneous abortion, preterm premature rupture of membranes, preterm birth, uterine rupture, cesarean delivery, placental abruption, and stillbirth. In one study, fetal death from maternal trauma was calculated to be 2.3 per 100,000 live births. **It is important to recognize that even minor mechanisms of injury may result in poor outcomes for the fetus and the mother.**

These patients may present as trauma activations through the emergency department; however, they also may present to labor and delivery triage. Thus it is crucial to have a coordinated and collaborative system to optimize timely obstetric and trauma care. By one estimate, as many as 1 in 3 pregnant patients admitted to the hospital for trauma will deliver during that hospitalization. Pregnancy induces alterations in the anatomy and physiology of most organ systems. These anatomic and physiologic changes alter the presenting signs and symptoms of injury, the approach to resuscitation, and the results of diagnostic testing. Pregnancy may also impact the pattern and severity of injury.

The possibility of pregnancy should be considered in any female of reproductive age. Therefore, laboratory testing should be used to evaluate for a possible pregnancy. If pregnancy is suspected, pelvic ultrasound should be used to establish gestational age and more detailed information (i.e., number of fetuses, placentation etc.). In one study, 3% of women admitted to a trauma unit were pregnant, and of these pregnancies, 11% were incidentally discovered. Therefore, every injured female of reproductive age should be considered pregnant until proven otherwise.

The care of the pregnant trauma patient involves two patients: the pregnant patient and the fetus. **The treatment priorities for an injured pregnant patient are the same as for a nonpregnant patient.** Effective resuscitation of the pregnant patient is the optimal treatment of the fetus. Use of left-uterine displacement during the assessment of the pregnant patient is critical to improving venous return and, therefore, maternal hemodynamics and fetal blood flow. Imaging that includes radiation exposure should not be withheld if indicated for the evaluation of the pregnant patient's injuries.

A qualified surgeon and obstetrician should be involved early in the evaluation of the pregnant trauma patient. If not immediately available, early consultation with and/or transfer to a trauma center with obstetric capabilities should be considered. In some practice settings, obstetrical care is routinely provided by midwives, family medicine specialists, or other obstetrics-related clinicians; although these clinicians may be of great value in the initial care, it does not negate the need for obstetrical consultation for the pregnant trauma patient, however it may be achieved (e.g., remotely).

MECHANISMS OF INJURY

BLUNT INJURY

The most common mechanisms of injury during pregnancy are motor vehicle crashes (MVCs, estimated 207 cases per 100,000 pregnancies) and slips/falls (estimated 48.9 cases per 100,000 pregnancies). MVCs are one of the leading causes of maternal and fetal mortality, resulting in maternal death in 1.4 per 100,000 pregnancies and fetal death in 3.7 per 100,000 pregnancies. Blunt abdominal trauma in the pregnant patient results in an increased risk of rupture of membranes, preterm labor, and preterm delivery.

A major risk factor for adverse outcomes during MVC is improper seat-belt use. Compared with restrained pregnant patients involved in collisions, unrestrained pregnant patients have a higher risk of premature delivery and fetal death. Using a lap belt alone or wearing a lap belt too high over the uterus can increase forward flexion or result in direct force to the uterus, increasing risk of uterine rupture or placental abruption.

There is less robust literature related to slips and falls during pregnancy. Increased joint laxity, center of gravity changes from the gravid uterus, weight gain, and decreased dynamic postural stability can contribute to increased risk of falls during pregnancy. Approximately 1-in-4 pregnant people will fall at least once during their pregnancy. The likelihood of falling with injury rises later in pregnancy, with one study finding that 79% of pregnant patients hospitalized after a fall were in their third trimester.

PENETRATING INJURY

The management of penetrating trauma does not differ in a pregnant patient. As the gravid uterus grows larger, the other viscera are relatively protected from penetrating injury; however, uterine injury incidence rises as it becomes an abdominal organ. The dense uterine musculature in early pregnancy can absorb a significant amount of energy from penetrating objects, decreasing their velocity and lowering risk of injury to other viscera.

■ **Figure 13-1: Estimated Incidence/Prevalence of Injury by Mechanism During Pregnancy.** The data on injury mechanism during pregnancy are hampered by heterogenous study designs and methodologies. However, domestic (or intimate partner) violence incidence and prevalence has been reported to be high during pregnancy; this includes sexual, physical, and psychological violence.

Estimated Incidence/Prevalence of Injury by Type of Trauma During Pregnancy

Mechanism of injury	Estimated incidence/ prevalence in pregnancy	Study design	Estimated incidence/ prevalence outside of pregnancy
Motor vehicle crashes	207/100,000 live births	Population-based cohort	1104/100,000 women
Falls and slips	48.9/100,000 live births	Retrospective case-control	3029/100,000 women
Burns	0.17/100,000 person-years	Retrospective case-control	2.6/100,000 person-years
Accidental poisoning	N/A	N/A	N/A
Domestic violence	8307/100,000 live births	Review	5239/100,000 women
Suicide	2/100,000 live births	Retrospective cohort	8.8/100,000 population
Homicide	2.9/100,000 live births	Retrospective cohort	2.3/100,000 women
Penetrating trauma	3.27/100,000 live births	N/A	3.4/100,000 women
Toxic exposure	25.8/100,000 person-years	Retrospective cohort	115.3/100,000 person-years

Literature relating to incidence of burns during pregnancy is limited to most severe cases admitted to burn units and referral centers. Rate for accidental poisoning during pregnancy could not be calculated from available published literature. Domestic violence incidence includes all forms of partner violence: sexual, physical, and psychological.
N/A, not available.
Rates exclude attempted suicides. Attempted suicide rate during pregnancy is approximately 40/100,000 pregnancies and during postpartum period is 43.9/100,000 live births. Rates include only causes leading to fatality. Rates calculated using 2009 US data from Centers for Disease Control and Prevention.
Mendez-Figueroa H, Dahlke JD, Vrees RA, Rouse DJ. Trauma in pregnancy: an updated systematic review. *Am J Obstet Gynecol.* 2013;209(1):1-10.

The amniotic fluid and fetus also absorb energy and contribute to slowing of the penetrating object. The resulting low incidence of associated maternal visceral injuries accounts for the generally excellent maternal outcome in case of penetrating wounds to the gravid uterus. Tragically, fetal outcome in general is poor when there is a penetrating injury to the uterus.

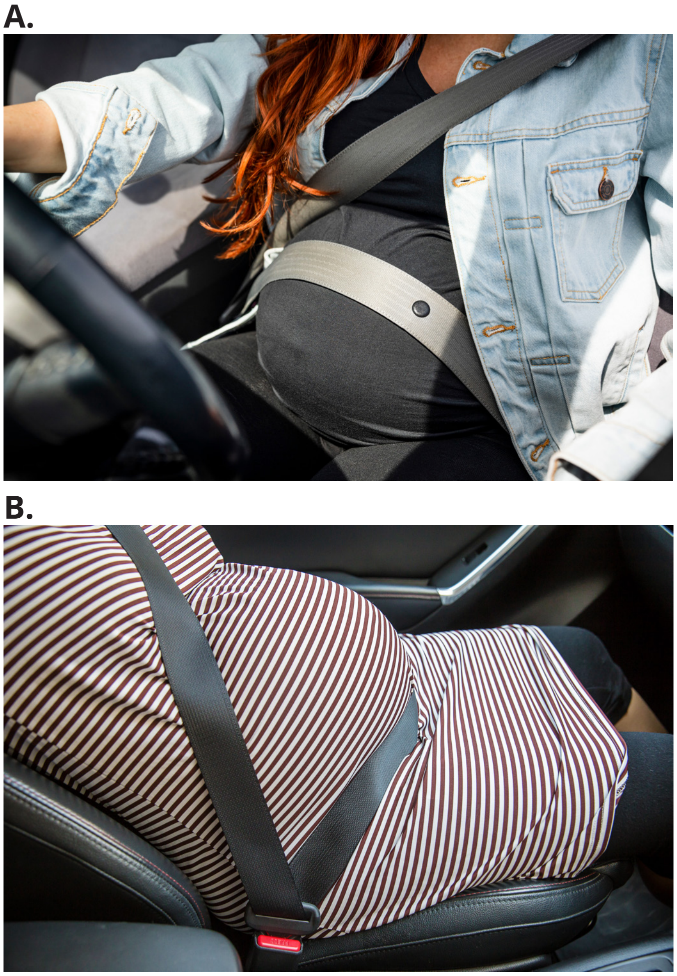
INTENTIONAL INJURY

Intentional trauma, unfortunately, is another common mechanism for traumatic injury in the pregnant patient. The most common cause of intentional trauma is intimate partner violence (IPV), which has been reported to occur in 4%–8% of all pregnancies; however, it is frequently underreported. There are patterns of injury that are associated with IPV, and it is imperative to have heightened awareness of this as a source of trauma. Proximal and midline injuries are more common than distal injuries in the setting of IPV. Trauma to the neck, breasts, face, upper arms, and lateral thighs are more commonly seen. Sequalae of IPV in pregnancy are extensive, including poor pregnancy weight gain, infection, anemia, stillbirth, pelvic fracture, placental abruption, fetal injury, preterm delivery, and low birth weight.

SEVERITY OF INJURY

The severity of maternal injuries significantly impacts maternal and fetal outcome. Therefore, treatment methods also depend on the severity of maternal injuries. All pregnant patients with major injuries require admission to a facility with trauma and obstetric capabilities. **Carefully observe pregnant patients with injuries, because even minor injuries can result in placental abruption and possibly fetal demise.**

■ Figure 13-2: Seatbelt Use During Pregnancy.
A. Demonstrates improper use of seatbelt—note that the lap belt is too high over the uterus. **B.** Demonstrates correct wearing of the lap belt and shoulder belt.



ANATOMIC AND PHYSIOLOGIC CHANGES IN PREGNANCY

An understanding of the anatomic and physiologic maternal alterations due to pregnancy, including the physiologic relationship between a pregnant patient and the fetus, is an essential foundation for providing appropriate and effective care to both patients. Such alterations include changes in anatomy, blood volume/composition, and hemodynamics, as well as changes in the respiratory, gastrointestinal, urinary, musculoskeletal, and neurological systems.

UTERINE CHANGES

The uterus is not commonly involved in trauma unless it is enlarged by pregnancy. The uterus remains an intrapelvic organ until approximately the 12th week of gestation. As the fetus grows, the uterus moves cephalad and becomes an abdominal organ. By 20 weeks, the uterus is at the level of the umbilicus, and at 34 to 36 weeks it reaches the costal margin (**■ Figure 13-3** and **■ Figure 13-4**). During the last 2 weeks of gestation, the fundus often lowers in location as the fetal head engages the pelvis.

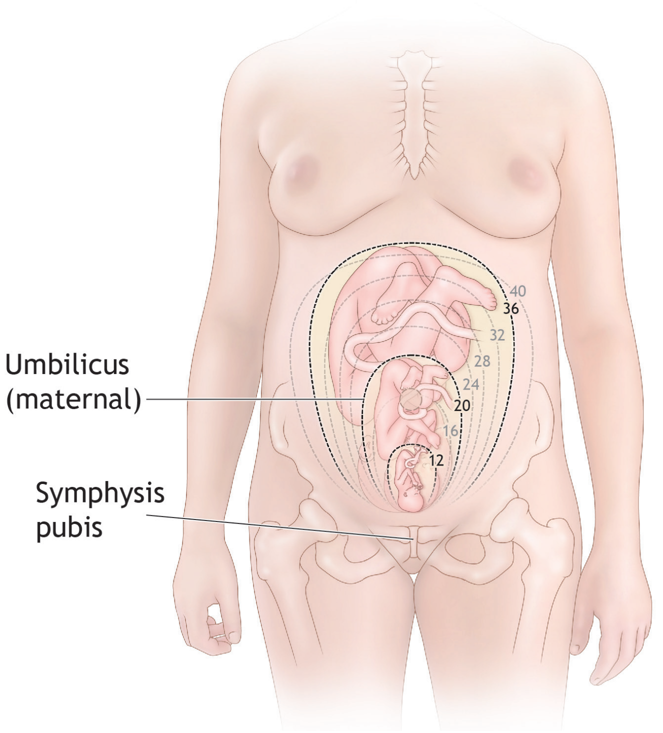
As the uterus enlarges, the intestines are pushed cephalad such that their location is primarily in the upper abdomen. As a result, the bowel is relatively protected from blunt or penetrating abdominal trauma, whereas the uterus and its contents (fetus and placenta) become more vulnerable to direct blunt or penetrating trauma. Penetrating trauma above the uterine fundus can result in complex intestinal injury due to this cephalad displacement. Clinical symptoms of peritoneal irritation are less evident in pregnant women due to the physiologic and anatomic changes of pregnancy; therefore, physical examination may be less informative, and the clinician should maintain a high index of suspicion for underlying intra-abdominal injury.

During the first trimester, the uterus is a thick-walled structure of limited size, confined within the bony pelvis. During the second trimester the uterus enlarges beyond the protected pelvic location. By the third trimester, the uterus is a large, thin-walled abdominal organ. The fetus remains cushioned by a generous amount of amniotic fluid. In the later third trimester, the fetus is usually in the vertex ("head-down") presentation, with the fetal head in the pelvis and the remainder of the fetus exposed above the pelvic brim. Pelvic injuries in late gestation can result in fetal skull fracture or serious intracranial injury to the fetus.

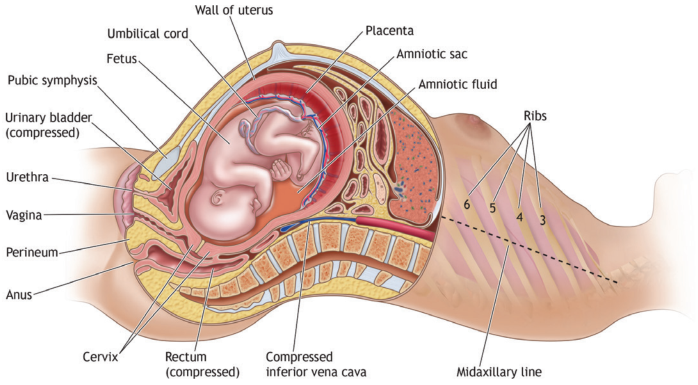
Unlike the myometrium, the placenta has little elasticity. This results in vulnerability to shear forces at the uteroplacental interface, which may lead to bleeding between the placenta and uterus, which can result in placental abruption. The placental vasculature is maximally dilated throughout gestation, yet it is exquisitely sensitive to catecholamine stimulation, which results in narrowing of this vasculature and a decrease in placental blood flow. The blood flow to the pregnant uterus is approximately 500 mL/minute (five times increased rate), which is significant considering the average total blood volume of a pregnant patient is 5000 mL.

Placental abruption may result in vaginal bleeding or may be concealed and less obvious. Placental abruption can result in significant blood loss. Heightened awareness and suspicion of a possible placental abruption is critical, especially in the setting of a pregnant patient who is showing signs and symptoms of blood loss without an obvious source. A rapid drop in maternal intravascular volume from placental abruption or another source can result in a profound increase in uterine vascular resistance, reducing fetal oxygenation despite reasonably normal maternal vital signs.

■ Figure 13-3: Changes in Fundal Height in Pregnancy. The gravid uterus becomes an abdominal organ after ~12 weeks, reaching the level of the umbilicus at ~20 weeks. The change in uterine size influences injury patterns with both blunt and penetrating trauma



■ Figure 13-4: Anatomic Changes in the Uterus in Late Pregnancy. As the uterus enlarges and occupies more of the maternal abdominal cavity, it and the fetus become more vulnerable to injury. The uterine wall also becomes thinner.



AIRWAY AND RESPIRATORY SYSTEM

Hyperemia and edema develop in the airway of the pregnant patient, which can make intubation considerably more difficult. There are also significant changes in the respiratory system during pregnancy, resulting in increased oxygen requirements and decreased pulmonary reserve. The respiratory system changes of pregnancy begin in the middle of the second trimester (20 weeks) and are progressive through term. These include a 30%–40% increase in tidal volume and an increase in minute ventilation, which accommodate for the 20% increase in maternal oxygen consumption in pregnancy, but result in maternal hypocapnia. There is a 25% decrease in functional residual volume, and this, coupled with the increased metabolic rate, result in a greater tendency toward oxygen desaturation in the setting of oxygen deprivation (less oxygen reserve). With this lower pulmonary reserve, there is less ability to compensate for acid-base imbalances.

The normal pregnant patient is in a state of compensated respiratory alkalosis. Therefore, it is imperative to maintain and ensure adequate arterial oxygenation when resuscitating injured pregnant patients. When indicated, it is critical that the airway be secured early and definitively by the most skilled airway clinician on the team.

Anatomic alterations in the thoracic cavity include elevation of the diaphragm by up to 4 cm cephalad and decreased thoracic compliance, which result in increased resistance to ventilation. Chest x-ray studies on pregnant patients often reveal increased lung markings and prominence of the pulmonary vessels.

CIRCULATION

Important hemodynamic factors to consider in pregnant trauma patients include blood volume, cardiac output, heart rate, blood pressure, and electrocardiographic changes.

BLOOD VOLUME AND COMPOSITION

Plasma volume increases steadily throughout pregnancy and plateaus around 34 weeks of gestation. A smaller increase in red blood cell volume occurs, resulting in a decreased hematocrit level. In late pregnancy, a hematocrit level of 31%–35% is normal. The combination of relatively young age and expanded plasma volume results in a healthy pregnant patient's ability to lose 1200–1500 mL of blood before exhibiting signs and symptoms of hypovolemia. While this volume of blood loss may not be reflected in maternal vital sign changes, it can still impact the blood flow to the uterus and result in fetal compromise as evidenced by an abnormal fetal heart rate.

White blood cell count increases during pregnancy. Normal pregnancy white blood cell counts range from 12,000 to 18,000; however, higher levels are not unusual during labor or stress. Levels of fibrinogen and other clotting factors are elevated in pregnancy. It is important to note that fibrinogen levels are elevated in pregnancy, and a level below 200 can indicate impending disseminated intravascular coagulation (DIC), a frequent comorbidity of placental abruption. Platelet count is also elevated during pregnancy. Prothrombin and partial thromboplastin times may be shortened, but bleeding and clotting times are unchanged. Viscoelastic testing, if available, can be helpful in the evaluation and management of the pregnant trauma patient (**■ Table 13-2**).

CARDIOVASCULAR CHANGES DURING PREGNANCY

During pregnancy, the heart rate gradually increases to 20% over baseline by the third trimester. Stroke volume also increases in pregnancy. Cardiac output is calculated by multiplying heart rate by stroke volume. Cardiac output increases during pregnancy by 40%–50% due to increases in both heart rate and stroke

■ **Table 13-1: Arterial Blood Gas (ABG) Values in the Pregnant vs. Nonpregnant Patient.** Anatomic and hormonal changes in pregnancy lead to changes in the ABG. Progesterone increase leads to respiratory alkalosis and a decreased resting $PaCO_2$. Functional Residual Capacity (FRC) and Expiratory Reserve Volume (ERV) also decrease as the uterus enlarges. Clinically, a patient in late pregnancy who has a $PaCO_2$ that would be normal in a nonpregnant patient (e.g., 40 mm Hg) should be evaluated for impending respiratory insufficiency.

Arterial Blood Gas (ABG) Values: Nonpregnant and Pregnant Patients

Nonpregnant	Pregnant
$PaCO_2$ 37–40 mm Hg	$PaCO_2$ 27–32 mm Hg ↓ (respiratory alkalosis)
pH 7.35–7.40	pH 7.40–7.45 ↑
PaO_2 75–100 mm Hg	PaO_2 105 mm Hg ↑
HCO_3 22–26 mmol/L	HCO3 18–21 mmol/L ↓

■ **Table 13-2: Normal Laboratory Values in the Pregnant vs. Nonpregnant Patient.** Pregnant patients have different "normal" lab values when compared to nonpregnant patients. Pregnant patients normally exist in a state of compensated respiratory alkalosis. In the third trimester, fibrinogen levels that might be normal in a nonpregnant patient may in fact indicate impending disseminated intravascular coagulation (DIC).

Normal Laboratory Values: Pregnant vs. Nonpregnant Patient

VALUE	PREGNANT	NONPREGNANT
Hematocrit	32%–42%	36%–47%
WBC count	5,000–12,000 µL	4,000–10,000 µL
Arterial pH	7.40–7.45*	7.35–7.45
Bicarbonate	17–22 mEq/L	22–28 mEq/L
$PaCO_2$	25–30 mm Hg (3.3–4.0 kPa)	30–40 mm Hg (4.0–5.33 kPa)
Fibrinogen	400–450 mg/dL (3rd trimester)	150 - 400 mg/dL
PaO_2	100–108 mm Hg	95–100 mm Hg

* **Compensated respiratory alkalosis and diminished pulmonary reserve**

volume. Twenty percent of cardiac output goes to the uterus during pregnancy. This increased cardiac output can be greatly impacted by the maternal position during the second half of the pregnancy. Aorta and vena cava compression by the gravid uterus impacts forward flow and venous return as early as 18 weeks pregnant. Cardiac output can be decreased as much as 30% in the supine position due to this aortocaval compression.

BLOOD PRESSURE

There is a reduced vascular resistance in pregnancy due to progesterone-mediated vascular changes. Systolic and diastolic blood pressure are decreased by 5–15 mm Hg in the second trimester. The combination of an increased cardiac output and decreased blood pressure result in a lower systemic vascular resistance.

ELECTROCARDIOGRAPHIC CHANGES

In the last half of the pregnancy, the heart is displaced cephalad and to the left due to the gravid uterus. In addition, the cardiac changes that occur due to the hemodynamic alterations of pregnancy impact the electrocardiograph pattern. Left axis deviation, flattened or inverted T waves in leads III and aVF, and the precordial leads may be normal. Ectopic beats often are increased during pregnancy. Electrocardiogram changes need to be evaluated cautiously due to the variations during pregnancy. This displacement of the heart can also alter the appearance on a chest x-ray.

NEUROLOGIC SYSTEM

Although there are no anatomic changes to the neurologic system during pregnancy, patients are at risk of preeclampsia and eclampsia. New-onset tonic-clonic, focal, or multifocal seizures in the absence of other causative conditions may be eclampsia. It is a rare complication of pregnancy that can occur after 20 weeks of gestation and can mimic head injury. Hypertension, hyperreflexia, proteinuria, thrombocytopenia, liver function abnormalities, coagulopathy, or pulmonary edema may be present in addition to the seizures in a patient with eclampsia. Expert neurological and obstetrical consultation can help differentiate eclampsia from other causes of seizures and initiate the appropriate treatment.

GASTROINTESTINAL SYSTEM

The hormonal changes in pregnancy result in decreased competence of the lower esophageal sphincter, resulting in increased risk of aspiration. Gastric emptying is delayed during pregnancy, so early gastric tube decompression should be considered, if indicated, to prevent aspiration of gastric contents. The pregnant patient's intestines are pushed up to the upper abdomen and may be shielded by the uterus. The solid viscera remain essentially in their usual anatomic positions, although it has been reported there is a 25% increased risk of hepatic or splenic maternal injury after blunt abdominal trauma.

URINARY SYSTEM

The glomerular filtration rate and renal blood flow increase during pregnancy, resulting in serum levels of creatinine and urea nitrogen decreasing to one-half of pre-pregnancy levels. Glycosuria is common during pregnancy.

MUSCULOSKELETAL SYSTEM

The pubic symphysis widens 4–8 mm, and the sacroiliac joint spaces increase by the seventh month of gestation. These factors must be considered in interpreting x-ray films of the pelvis.

The large, engorged pelvic vessels surrounding the gravid uterus can contribute to massive retroperitoneal bleeding after blunt trauma associated with pelvic fractures.

APPROACH TO THE PREGNANT TRAUMA PATIENT: INITIAL ASSESSMENT PRIMARY SURVEY

To optimize outcomes for the pregnant patient and the fetus, clinicians must assess and resuscitate the pregnant patient first, followed by assessment of the fetus before performing the secondary survey.

Early obstetric consultation and notification should be part of the algorithm for trauma in pregnancy, adjusted for institutional resources. Ideally, if obstetric services are available in the facility, they should be notified at the same time as the trauma team for timely response in the event of a known trauma in the second half of pregnancy (20 weeks or more). If the pregnancy is at the age of viability (22 weeks or more), consider notifying pediatrics and/or the newborn ICU. If obstetrics is not available locally, early telephone consultation should be made.

The goals of the primary survey for the pregnant patient are the same as the goals outlined for the nonpregnant patient. Goal number one is to resuscitate the pregnant patient, and goal number two is to save the fetus. Fetal outcomes are directly related to maternal resuscitation. Maternal shock and death are the leading cause of fetal death. It is important to focus on the initial resuscitation and stabilization of the maternal patient while simultaneously optimizing the blood flow to the fetus during the primary survey. The best way to treat the fetus is to treat the mother first. There are a few special considerations to keep in mind during the primary survey for the pregnant patient.

EXSANGUINATING EXTERNAL HEMORRHAGE

Evaluation of the pregnant patient for massive external hemorrhage is performed in the same manner as for nonpregnant patients. Follow the same principles for pregnant patients as for nonpregnant patients, including application of direct pressure, wound packing, and placement of tourniquets as indicated.

AIRWAY

Due to the respiratory changes and increase in oxygen requirements during pregnancy, there is a greater tendency toward oxygen desaturation in the setting of oxygen deprivation. It is important to ensure a patent and secure airway by endotracheal intubation or adjunct measures if indicated, avoiding delays. The hyperemia and edema often seen in the airway of the pregnant patient mandate that all such airways be considered a "difficult airway" and appropriate measures be taken.

If intubation is indicated, it should be performed by the most skilled clinician on the team early in the resuscitation. Intubation with a smaller endotracheal tube is recommended (size 6 or 7) due to possible airway swelling and engorgement. Decreased lower-esophageal sphincter tone and delayed gastric emptying significantly increases the risk of aspiration, and measures should be taken to minimize the risk using principles of rapid-sequence intubation.

BREATHING

Clinicians should be cognizant of the alteration in PCO_2 baseline as pregnancy progresses, with a PCO_2 of 30 mm Hg being normal in pregnancy. Understanding normal blood gas values in pregnancy is important in the recognition that a PCO_2 of 40 mm Hg may indicate relative respiratory acidosis and impending respiratory failure. Administer supplemental oxygen to maintain an oxygen saturation greater than or equal to 95%. Maternal oxygen consumption is elevated at baseline, and there is less oxygen reserve. The fetus is very sensitive to maternal hypoxemia.

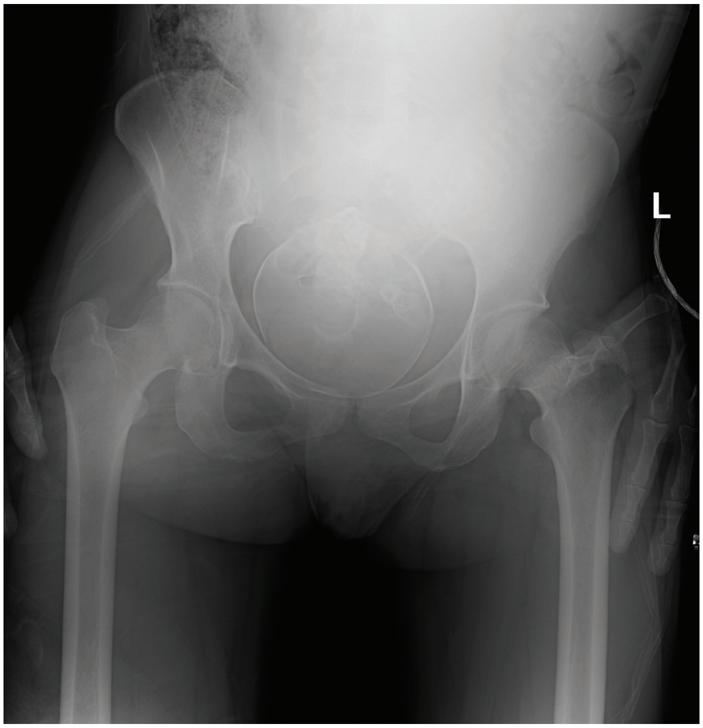
If chest tube placement is necessary, it is important to consider the stage of pregnancy and account for the diaphragmatic position changes as pregnancy progresses. The diaphragm may be elevated as much as 4 cm by the end of pregnancy; therefore, chest tube placement should be higher than the usual fourth intercostal space (ideally the second or third intercostal space) in order to avoid intra-abdominal placement.

CIRCULATION

Because of their increased intravascular volume, pregnant patients can lose a significant amount of blood before tachycardia, hypotension, and other signs of hypovolemia occur. In this setting, despite a stable-appearing patient, maternal hypovolemia can negatively impact both the patient and the fetus. Administer appropriate crystalloid and/or blood products early for volume replacement, as needed to support the physiologic hypervolemia of pregnancy. Vasopressors should not be first-line therapy in a pregnant trauma patient in hemorrhagic shock *(see Chapter 6, Circulation Assessment and Volume Resuscitation)*. Vasopressors can further reduce uterine blood flow, resulting in fetal hypoxia.

The massive transfusion protocol should be activated early in pregnant trauma patients when there is concern for hemorrhagic shock. The components will vary based upon institutional protocols and resources, but emergency-release O-negative blood products (packed red blood cells or whole blood) are preferred to avoid Rh sensitization (alloimmunization) in Rh-negative women. Use standard ratios of blood products or whole blood, if available. When Rh-negative products are not available, using Rh-positive, ABO-compatible products is preferable to inadequate resuscitation. **Stabilizing the pregnant patient is the top priority. Concerns for Rh sensitization and subsequent prevention can be addressed after stabilization.** Rh sensitization needs to be treated within 72 hours, and consultation with an obstetrician or blood bank director can help determine timing and dosage. Tranexamic acid has been studied in pregnancy as an adjunct for patients undergoing vaginal or cesarean delivery as well as for postpartum hemorrhage, with favorable or mixed results. It is considered safe for the fetus in setting of trauma with significant bleeding, though it is currently unknown if the use of tranexamic acid in the pregnant trauma patient reduces mortality.

■ **Figure 13-5: Pelvic Film in Pregnant Patient.** Pelvic vessels become engorged in the pregnant patient. Pelvic fractures and associated vascular trauma can lead to massive retroperitoneal hemorrhage.



Large-bore IV access should be secured above the diaphragm. Given the potential for the gravid uterus compressing the inferior vena cava (IVC) and pelvic vessels, IV fluids and medications administered through access below the diaphragm may not easily reach the central circulation. If IO access is required, the humerus is the preferred site. Lower extremity venous access should be avoided due to vascular congestion in the pelvis and lower extremities secondary to IVC compression by the gravid uterus.

The gravid uterus can compress the vena cava as early as 18 weeks of gestation, resulting in significant reduction in venous return to the heart. Vena cava compression by the gravid uterus in the supine position can reduce cardiac output by as much as 30% and cause hypotension. **Manual displacement of the uterus to the left side can relieve the pressure on the IVC and improve hemodynamics.** If the patient requires spinal motion restriction in the supine position, the uterus can be manually displaced to the left, or if additional hands are not available, the patient can be tilted to the left 15–30 degrees and supported with a bolstering device, optimizing maternal cardiac output while maintain spinal motion restriction (■ **Figure 13-8**). Lateral tilt/left uterine displacement can increase cardiac output as much as 25%, improving the patient's hemodynamics.

DISABILITY

As stated previously, pregnant patients are at risk for the development of preeclampsia/eclampsia. The development of new-onset tonic-clonic, focal, or multifocal seizures in the absence of other causative conditions may be eclampsia and **is a neurologic emergency**. It is a rare complication of pregnancy that can occur after 20 weeks of gestation and can mimic head injury. Hypertension, hyperreflexia, proteinuria, thrombocytopenia, liver function abnormalities, coagulopathy, or pulmonary edema may be present in addition to the seizures. Prompt, expert neurological and obstetrical consultation can help differentiate eclampsia from other causes of seizures and initiate the appropriate treatment.

EXPOSURE/ENVIRONMENT

The principles of complete exposure followed by avoidance of hypothermia apply to pregnant patients, as they do in all trauma patients. See section later in this chapter for information regarding appropriate examination of the vaginal vault.

ADJUNCTS TO PRIMARY SURVEY/ RESUSCITATION

The FAST exam is an important adjunct to the Primary Survey and can be modified to include fetal information if qualified personnel are available. The fetal FAST exam is performed alongside the traditional FAST exam. It evaluates number of fetuses, presentation of the fetus, position of placenta, amniotic fluid volume, cardiac activity, and fetal femur length (>4 cm is estimated to be viable). **In the event of maternal instability, this evaluation should not delay maternal interventions.** In the absence of ability to perform fetal FAST, ultrasound or Doppler should be used to measure the fetal heart rate (■ **Table 13-3**).

■ **Table 13-3: Fetal FAST.** Performing a fetal ultrasound alongside the Focused Assessment with Sonography in Trauma (FAST) can provide valuable information about the status of the fetus. However, maternal resuscitation should not be delayed in order to perform this diagnostic test.

Fetal FAST	
Number	1/2/3+
Position	cephalic/breach/transverse
Placentation	low/fundal/anterior/posterior
Fluid volume	normal/low/high
Cardiac activity	normal/abnormal/absent
Femur length	____ cm (consider viable if >4cm)

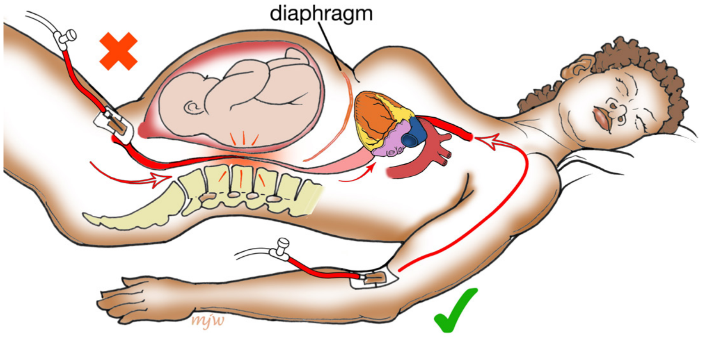
Source: MacArthur MacArthur B, Foley M, Gray K, Sisley A. Trauma in Pregnancy: A Comprehensive Approach to the Mother and Fetus. *Am J Obstet Gynecol.* 2019;220(5):465-468.e1. doi: 10.1016/j.ajog.2019.01.209. Epub 2019 Jan 24. PMID: 30685288.

■ **Figure 13-6: ATLS Maternal Fetal Trauma Checklist.** Note that the Primary Survey should follow the same sequence as with a nonpregnant patient. Some details in the sequence, such as Lateral Uterine Displacement to improve circulation, are added in consideration of the pregnancy.

ATLS Maternal-Fetal Roles and Responsibilities		
	TRAUMA TEAM	**OBSTETRIC TEAM**
Before the patient arrives (if possible)	○ Notify obstetric team and share details of the event ○ Ensure that the ultrasound machine is readily available	○ Introduce obstetric team to the trauma team ○ Place fetal monitoring belts on the bed
	Huddle between the Trauma and Obstetric teams to review roles.	
Primary Survey	○ **eXsanguinating eXternal Hemorrhage:** Evaluate and control massive eXternal hemorrhage using direct pressure, wound packing, and placement of tourniquets as indicated ○ **Airway:** Ensure patient airway and cervical spine spine motion restriction if indicated ○ **Breathing:** Supplemental oxygen; interventions as indicated ○ **Circulation:** IV/IO access; distal pulses; perform lateral/left uterine displacement (LUD) if indicated; other interventions as indicated ○ **Disability:** Focused Neurologic Exam: GCS, pupil size and response; lateralizing findings ○ **Exposure/Environment**: Discover all external wounds; prevent hypothermia ○ **Resuscitation** as indicated	○ Ensure that LUD is performed if indicated ○ Observe at the bedside (mental status; vaginal leaking and/or bleeding; abdominal tenderness)
Primary Survey Adjuncts	○ Consider Focused Assessment with Sonography for Trauma (FAST) ○ Consider laboratory tests: ABG, lactate ○ Consider portable imaging: Chest, pelvis ○ Type and Cross-match ○ Serial Physical Examination	○ Consider Fetal FAST examination if appropriate • Number: 1/2/3+ • Presentation: Cephalic/breech/transverse • Placentation: Low/fundal/anterior/posterior • Amniotic fluid volume: Normal/low/high • Cardiac activity: Normal/abnormal/absent • Femur length: ____ cm (consider viable if >4cm)
Secondary Survey	○ Head-to-toe examination: • Head, Face, Eyes, Ears, Neck • Chest • Abdomen/Pelvis • Genitalia • Back • Extremities ○ AMPLE History: allergies, medications, past illnesses and surgeries, last oral intake, events leading to injury	○ Initiate electronic fetal monitoring (if appropriate) after spine and abdominal examination ○ Focused obstetric history (**CODE**) • **C**omplications of pregnancy • **O**bstetric history and prenatal care clinician • **D**ating method and estimated due date • **E**vent details, including leaking, bleeding, contractions, and fetal movement
Secondary Survey Adjuncts	○ Consider computed tomography or x-ray imaging ○ Continue fetal monitoring when appropriate	○ Electronic fetal monitoring for 6 hours, extend to 24-hour electric fetal monitoring, if >6 contractions per hour in any single hour ○ Abruption laboratory tests (complete blood count, fibrinogen, fetal maternal hemorrhage test (Kleihauer Betke or flow cytometry) ○ Give RhIG if RH-negative ○ Obstetric ultrasound scan: placentation, estimated fetal weight, amniotic fluid levels ○ Obtain prenatal records
Debriefing and Disposition	○ If indicated, designate where exploratory laparotomy or cesarean delivery will occur and who will be responsible for the incision. ○ Summarize the findings and initial plan of care, including immediate disposition of the patient. ○ Exchange contact information and update both teams with any change in maternal or fetal status.	

ABG, Arterial Blood Gas; GCS, Glasgow Coma Scale; LUD, Left-uterine displacement.

■ **Figure 13-7: IV Access in the Pregnant Patient.** Because late in pregnancy the gravid uterus can compress the vena cava, fluids administered via femoral or lower extremity lines may be less effective. When possible, venous access should be obtained above the diaphragm. The humerus is the preferred site for intraosseous access.

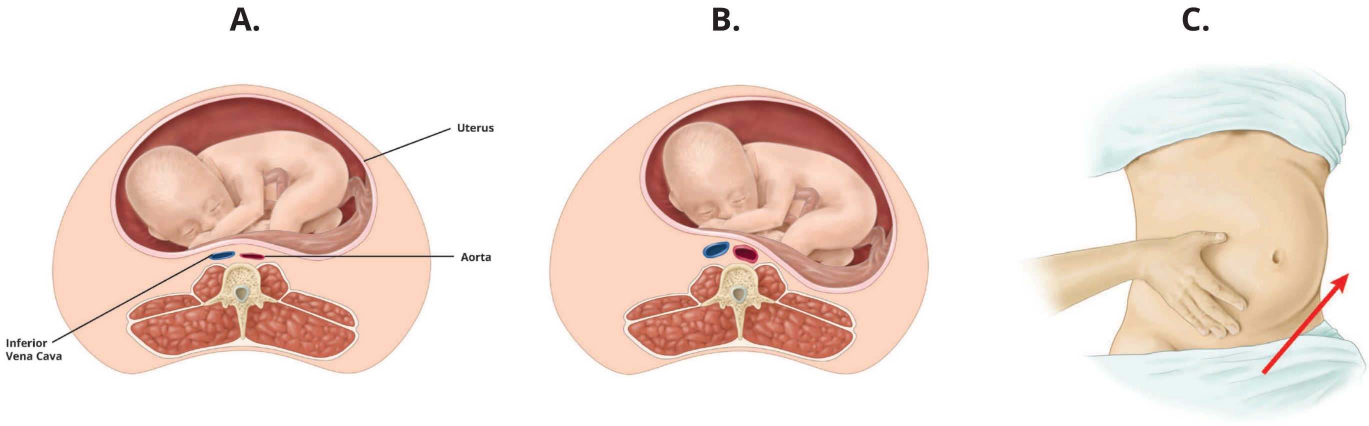


SECONDARY SURVEY

The maternal secondary survey should, in general, follow the same pattern as for nonpregnant patients *(see Chapter 14, Initial Assessment: Secondary Survey)*. The obstetric team, if present, should obtain a focused history including gestational age, parity, mode of prior deliveries, and any complications with the pregnancy.

The focused allergies, medications, past medical history, last meal and events leading to presentations (AMPLE) history should be augmented in the pregnant patient with a focused obstetric history, including complications of pregnancy, obstetric history, prenatal care clinician, dating method for estimated due date, and event details including leaking, bleeding, contractions, and fetal movement (**■ Table 13-4**).

■ **Figure 13-8: Lateral/Left Uterine Displacement.** Compression of the vena cava in pregnancy can decrease venous return as much as 30%. Manual displacement or “tilting” of the uterus to the left can improve hemodynamics. **A.** Internal view, before displacement **B.** Internal view, after displacement **C.** External view



■ **Table 13-4:Focused Obstetric History (CODE).** Supplementing the AMPLE history with the CODE history allows the physician to obtain information specifically related to the patient's pregnancy and obstetric history.

Focused History (CODE)	
C	**C**omplications of pregnancy
O	**O**bstetric history and prenatal care clinician
D	**D**ating method and estimated due date
E	**E**vent details, including leaking, bleeding, contractions, and fetal movement

Laboratory studies should include a complete blood count, comprehensive metabolic profile, type and screen (which will provide Rh status information), fibrinogen, and coagulation profile. Viscoelastic studies should be obtained if indicated and available. A fetal hemorrhage screen or Kleihauer-Betke (KB) test may be obtained in Rh-negative patients. However, clinicians should be aware that neither test reliably predicts fetal-maternal bleeding, but they may be used to quantify such bleeding for Rh immunoglobulin dosing in appropriate patients.

EVALUATION OF THE PERINEUM AND VAGINA

Evaluation of the perineum should be done as in the nonpregnant patient, with special attention to any vaginal bleeding or leaking of fluid from the vagina. This can be accomplished by visual inspection and limited vaginal exam as indicated during the secondary survey. Be sure to obtain consent from the awake patient prior to doing this—and any—exam. In the absence of vaginal bleeding or suspicion of impending delivery, it is generally not feasible or ideal to do a full pelvic exam and evaluation of the cervix in the trauma bay. This can be performed as indicated later in the evaluation and care of the patient in coordination with the obstetric consultant.

FETAL MONITORING

During the secondary survey, electronic fetal monitoring should be initiated after completion of abdominal examination and log roll for spinal examination. Placement of electronic fetal monitoring should not delay ongoing maternal workup, including imaging studies, and timing will vary pending institutional workflow.

If imaging is urgently needed and a fetal FAST exam has documented a normal fetal heart rate, fluid, and placenta without findings suspicious for placental abruption, then proceed to imaging. If a portable fetal monitor is available, continued fetal heart and uterine monitoring can be accomplished during transport.

Early fetal heart rate and uterine activity monitoring (tocometry) is important to monitor for placental abruption and fetal well-being. However, **initiation and maintenance of fetal monitoring and tocometry should never compromise timely work-up of and intervention for the pregnant patient, as resuscitation of the mother is always the primary priority for resuscitation of the fetus.** Because placental perfusion and oxygenation are dependent on maternal cardiopulmonary function, fetal monitoring should be continued in any setting where there is concern for maternal cardiopulmonary compromise.

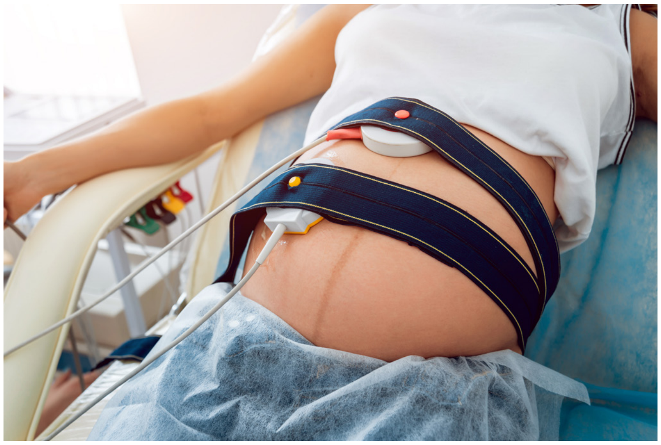
DEFINITIVE CARE

In the evaluation of the pregnant trauma patient, the determination of the best destination for definitive care will hinge on two major considerations. First, does the patient require admission for their traumatic injuries? Second, does the patient require evaluation or observation from an obstetric perspective? If so, does the current facility have the resources to provide definitive care? If the patient does require transfer, it is important to consider if the receiving facility can also provide the level of obstetric care and monitoring the patient will require. This will be dependent on gestational age and ideally is a collaborative decision between trauma and obstetric clinicians. When determining destination for patients based on estimated gestational age of the fetus, it is important to assess the neonatal ICU capabilities of the facilities in question.

If a patient does not require admission for their traumatic injuries, admission for maternal/fetal monitoring may be recommended. It is important to involve an obstetric consultant, either in person or by phone, early in the evaluation to help make this determination.

Placental abruption is the second-leading cause of fetal death in cases of trauma, and electronic fetal monitoring is the most sensitive and immediately available means to detect it. **A minimally injured pregnant patient may still require admission for fetal monitoring to rule out placental abruption**. This emphasizes the importance of early involvement of the obstetric team, either at your facility or at the tertiary care facility with both trauma and obstetric services.

■ **Figure 13-9: Fetal Monitoring.** External fetal monitoring illustrated in the figure is an important adjunct to the monitoring of the fetus. Fetal distress may also herald an emerging cardiopulmonary issue in the mother.



SPECIAL CONSIDERATIONS IN THE PREGNANT PATIENT

IMAGING

In general, imaging studies should be performed as clinically indicated regardless of pregnancy status, particularly in a high-energy mechanism of trauma with concern for maternal injury or instability. Per the American College of Obstetricians and Gynecologists/Eastern Association for the Surgery of Trauma, radiation less than 5 rads (50 mGy) is thought to pose little to no risk of teratogenicity or fetal loss. Imaging for trauma evaluation, including CT scans, is generally well below this threshold. No study to date has shown increased teratogenicity above baseline at fetal exposures below 10 rads. The fetus is most at risk for central nervous system (CNS) effects at 8–15 weeks gestational age; the threshold appears to be at least 20–40 rads. Image as needed to appropriately treat the patient. Consult a radiologist for assistance with dose calculation to decrease total exposure if there is the expectation that numerous studies will be needed and/or a possibly alteration in protocols. Be judicious and reduce redundancy as much as possible.

After the initial evaluation of the pregnant trauma patient, in the setting of hemodynamic stability, a more focused obstetric ultrasound can be performed to closely evaluate the placenta, obtain an estimated fetal weight, and estimate amniotic fluid volume. Additionally, the patient's prenatal records should be obtained if feasible. Such investigations should not delay transport to definitive care.

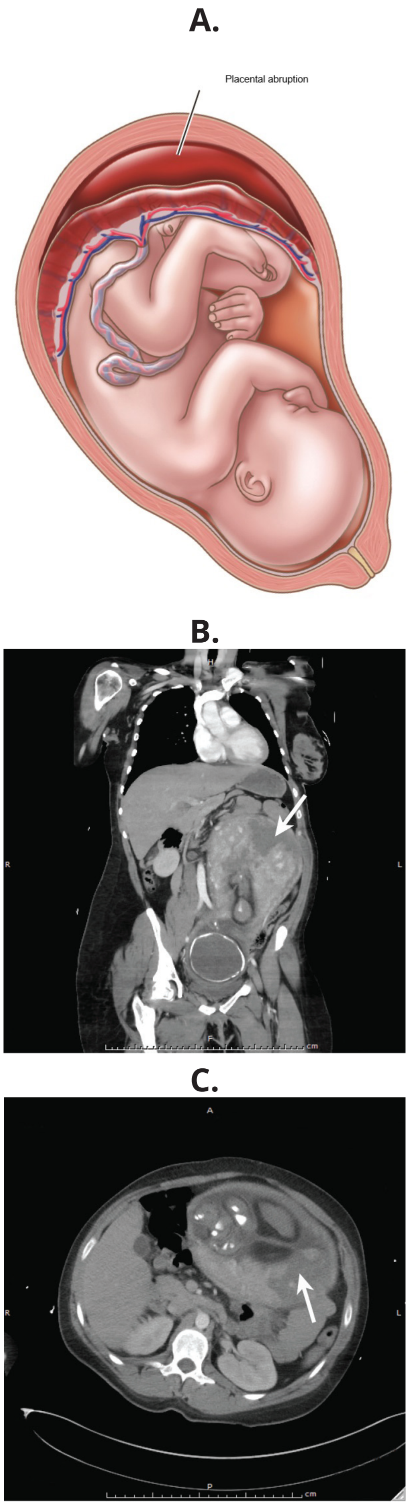
PLACENTAL ABRUPTION

When the mechanism of the trauma includes acceleration/deceleration forces to a pregnant patient's gravid uterus, the increased risk of placental abruption is a primary concern. There are two major mechanisms of uteroplacental interface failure described in the literature: shear force (strain) failure and tensile failure (contrecoup mechanism).

The uterus is compliant (flexible); however, the placenta is less compliant (rigid), which can result in failure of the placental attachment (uteroplacental interface failure) in the setting of acceleration/deceleration forces. These differences in tissue properties exacerbate the shearing forces that occur when the gravid uterus absorbs the energy from blunt force, resulting in disruption of the attachment of the placenta from the uterus. Placental abruption occurs in as many as 40% of severely injured women. Placental abruption may initially be concealed when there is bleeding between the placenta and uterus without vaginal bleeding. Most placental abruptions present within 6 hours of the trauma; however, they have been reported to present as much as 24 hours after trauma. **Uterine contractions are the most sensitive predictor of placental abruption. The classic triad of abruption includes contractions, bleeding, and abdominal pain.** Even if monitoring technology or laboratory tests are unavailable, the presence of findings on physical examination should prompt the clinician to consider placental abruption. Similarly, if the patient is hypotensive without a source, placental abruption must be considered. **Placental abruption may occur with even minor mechanisms of injury.**

■ **Figure 13-10: Placental Abruption:** The placenta is less compliant than the uterus itself which can lead to failure of the placental attachment in the setting of trauma. **A.** Illustration of blood/hematoma associated with placental abruption. **B.** Coronal CT image: arrow points to blood/hematoma associated with placental abruption. **C.** Axial CT image of same patient.

Placental abruption can occur with acceleration/deceleration mechanisms and is often manifested by the triad of uterine contraction, bleeding, and abdominal pain.



Diagnosis of placental abruption is dependent on clinical monitoring, including electronic fetal monitoring and tocometry. Ultrasound has been shown to be unreliable in diagnosing placental abruption, with sensitivity as low as 24% in one study. CT scan performs better than ultrasound at detecting clinical abruptions, with a sensitivity of 100% and specificity of 54%–56%. A KB test is not a reliable test for abruption.

Placental abruptions have been reported to occur up to 24 hours after a traumatic insult, but they have not been reported if uterine contractions are occurring less frequently than every 10 minutes during the initial 4-hour period of monitoring.

RH STATUS AND FOLLOW-UP CONSIDERATIONS

Approximately 15%–17% of the population has Rh-negative blood; the remainder has Rh-positive blood. If a pregnant trauma patient has Rh-negative blood, there is a significant likelihood the fetus has Rh-positive blood. As early as 6 weeks of gestation, the fetus has well-developed red blood cells. Traumatic placental injury can result in fetal-maternal hemorrhage, which can trigger an Rh-negative pregnant patient's immune system to develop antibodies against the Rh antigen if the baby has Rh-positive blood. This can cause problems in future pregnancies. Rh immunoglobulin is available to prevent this sensitization from occurring.

Rh immunoglobulin administered up to 72 hours after a fetal-maternal bleed can prevent Rh sensitization. A KB test or flow cytometry identifies the presence and quantifies the volume of fetal red blood cells in the maternal circulation. **All pregnant trauma patients who are Rh negative should be administered at least one dose of Rh immunoglobulin, even if the KB or flow cytometry is negative or if the tests are not available**. The standard dose of Rh immunoglobulin is 300 micrograms, which is adequate for a 30 mL fetal whole blood loss or less. In the setting of hemorrhagic shock in a pregnant patient, the benefits of the administration of low-titer O-positive whole blood outweighs the risks of Rh sensitization. A recent study reported a 3%–20% risk of Rh sensitization, which can be addressed after stabilization.

MATERNAL CARDIAC ARREST AND RESUSCITATIVE CESAREAN DELIVERY

Maternal cardiac arrest (MCA) in the setting of trauma should follow Advanced Cardiac Life Support® (ACLS®) guidelines, with a focus on correction of trauma-related etiologies of the arrest. Current guideline recommendations in the setting of pregnancy include no modification of hand placement for compressions. Furthermore, the patient should remain supine with manual uterine displacement (rather than tilting); this improves effectiveness of chest compressions.

In a hospital with surgical capabilities and in the setting of MCA, resuscitative cesarean delivery (RCD) should be considered to improve maternal physiology and potentially save the fetus. Perimortem cesarean delivery has been defined as the delivery of the fetus(es) during MCA or after maternal death and was often considered a procedure of last resort to save the fetus.

However, recent data have shown that early and rapid evacuation of the uterus (even if the fetus is nonviable) may result in a greater than 50% probability of maternal return of spontaneous circulation. This is thought to be due to the resultant diminished aortocaval compression, the decreased blood flow demand of the uterus, and improved blood return to the heart. Therefore, to emphasize the resuscitative benefits of delivery in the setting of MCA, the phrase "perimortem cesarean delivery" has been replaced with the more accurate and positive term "resuscitative cesarean delivery." **It is vital that the resuscitation team does not focus on fetal status but rather on the correction of the etiologies of the MCA and high-quality chest compressions/ACLS as indicated.** In a pregnant patient who experiences cardiac arrest, RCD should be considered if the uterus is at or above the umbilicus and the patient remains without return of spontaneous circulation after 5 minutes of appropriate resuscitation, regardless of fetal cardiac activity. Institutions are encouraged to develop protocols for RCD that include guidance for when it should be performed and what personnel and other resources must be available.

TRAUMA-INFORMED CARE AND THE PREGNANT PATIENT

A pregnant patient who has sustained trauma may have increased psychological stress and be more concerned about the status of the fetus than their own condition. Clinicians should take care not to interpret this anxiety as "uncooperative" or "noncompliant," even when the patient seems reluctant to follow certain care recommendations. Reassure the patient that the best way to help the fetus is to tend to the pregnant patient first. Pregnant patients may be concerned about fetal radiation exposure; explaining the importance of avoiding missed injuries and the low risk of fetal damage is important. **The language used when communicating with the pregnant patient about these issues is also key; it is recommended to use the words "mother" and "baby" instead of "patient" and "fetus" during these conversations.**

INTIMATE PARTNER VIOLENCE (IPV)

IPV is defined as physical or sexual violence, stalking, reproductive coercion, and psychological aggression by a current or former intimate partner of the victim. There is conflicting information about whether pregnancy increases the risk of IPV, but at least one comprehensive review suggests that women who have a partner with a history of IPV, substance abuse problems, or unemployment are at increased risk of experiencing IPV during pregnancy. In some cases, the pregnancy itself may trigger or exacerbate existing problems in the relationship, leading to an increase in IPV. All patients should be screened for IPV regardless of gender identity, sexual preference, geographic location, income, education, race, ethnicity, age, or professional role. **Clinicians should be particularly attuned to the risk of IPV in pregnant patients, conduct appropriate screening, and arrange access to resources as indicated.** See *Chapter 18, Injury Prevention,* for additional information.

CHAPTER SUMMARY

Important and predictable anatomical and physiological changes occur during pregnancy and can influence the assessment and treatment of injured pregnant patients. Given that the most common cause of fetal mortality is maternal mortality, stabilization of the pregnant patient should always be the initial priority in resuscitation of the pregnant trauma patient. Modifications to common interventions need to be considered in the alter stages of pregnancy due to anatomic changes related to the gravid uterus. This includes supine hypotension, where the gravid uterus can cause caval compression resulting in hypotension. Placental abruption is another important cause of fetal mortality in trauma and should be considered even in the minimally injured pregnant trauma patient. Qualified trauma and obstetric clinicians should be consulted early in the evaluation of the pregnant trauma patient, and if these services are not readily available, transfer should be considered immediately.

KEY LEARNING POINTS

- **Important and predictable anatomical and physiological changes occur during pregnancy and can influence the assessment and treatment of injured pregnant patients.**
- **The most common cause of fetal mortality is maternal mortality. Resuscitation of the pregnant patient and optimization of the fetal environment should be the initial priority in treatment of the pregnant trauma patient/fetus duo.**
- **Modifications to common interventions need to be considered in later stages of pregnancy due to anatomic changes related to the gravid uterus. Chest tube placement should be moved cephalad, and IV/IO access should be obtained above the diaphragm.**
- **The gravid uterus can cause caval compression in the supine position as early as 18 weeks of gestation. This can decrease cardiac output as much as 30%. Left-uterine displacement is an important adjunct to the primary survey in the pregnant trauma patient, improving hemodynamic status.**
- **Placental abruption is a significant cause of fetal mortality after trauma, and may occur with minor mechanisms of injury. It is primarily a clinical diagnosis, guided by observation, fetal heart rate monitoring, and tocometry. Most placental abruptions can be detected within 6 hours of trauma, but they have been reported as late as 24 hours after trauma.**
- **Early consultation with an obstetric consultant, in person or by telephone, is an important component for comprehensive care of the pregnant trauma patient. Obstetric consultants can assist in determining the need for and duration of any fetal monitoring after trauma.**
- **All Rh-negative patients should be administered Rh immunoglobulin after trauma within 72 hours. Obstetrical consultation is recommended, and resources are also available for determining the dosage, route, and timing of administration.**
- **Presence of indicators that suggest IPV should serve to initiate further investigation and protection of the patient.**

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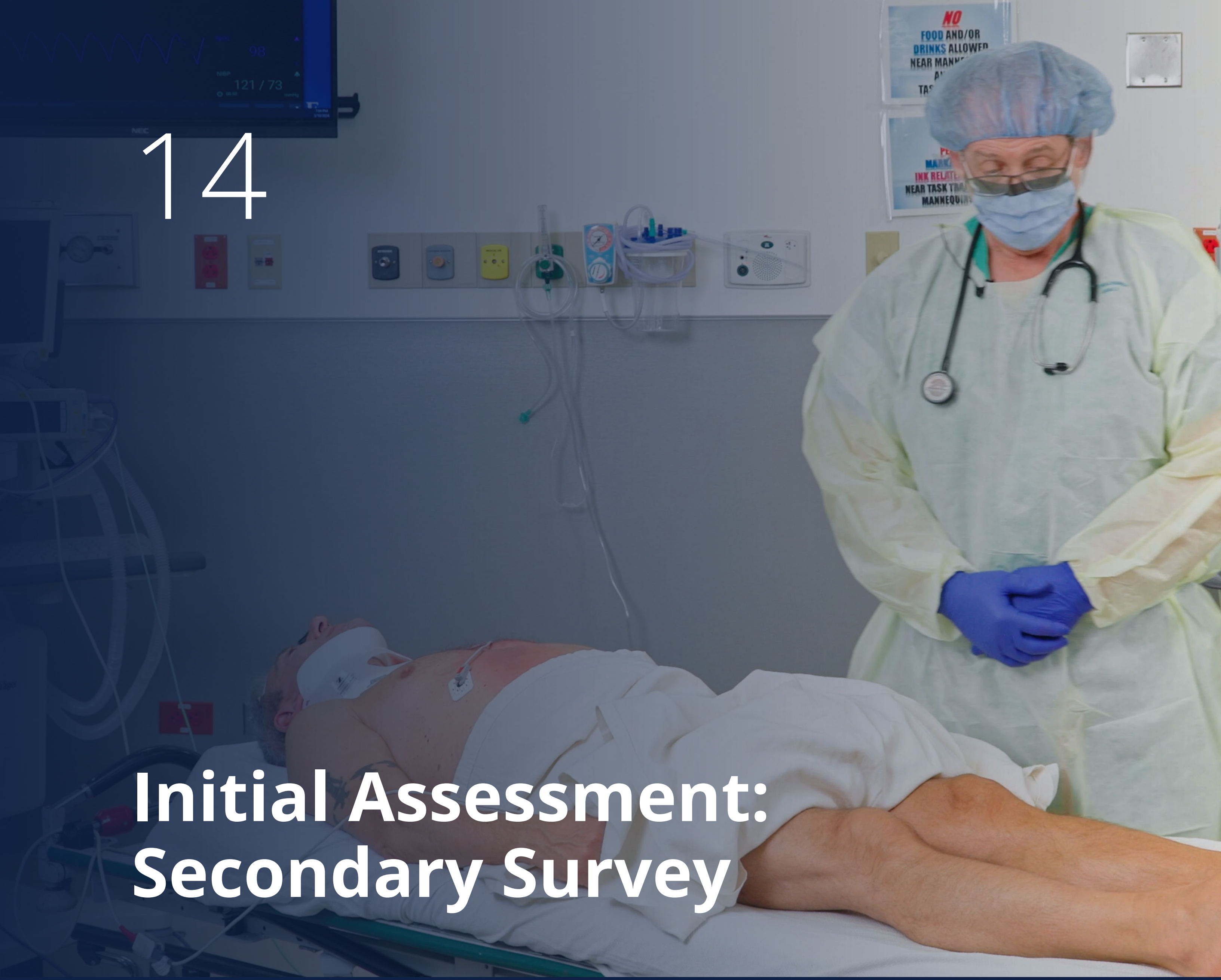
14



Initial Assessment: Secondary Survey

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Determine the appropriate time during patient evaluation to perform the secondary survey
2. Describe the components of the secondary survey
3. Recognize the importance of performing a comprehensive examination of the patient after the immediate potential life threats have been identified and treated
4. Determine the appropriate timing and sequence of extremity tourniquet evaluation and conversion to hemostatic dressing

14

Initial Assessment: Secondary Survey

CHAPTER STATEMENT

The secondary survey is a vital component of the work-up of patients with traumatic injuries. The role of the secondary survey is to identify all injuries. The secondary survey includes a detailed medical history, a description of the events surrounding the injury, a comprehensive physical examination, and laboratory and imaging studies necessary to identify injuries and monitor resuscitation. The secondary survey begins after the primary survey is completed in hemodynamically normal patients or after an unstable patient responds to resuscitation. The secondary survey does not begin until the primary survey has been completed and the patient is hemodynamically normal or improved.

INTRODUCTION

While the goal of the primary survey is to identify and treat injuries that pose an immediate threat to life, the role of secondary survey is to identify all injuries. This can be a daunting task, particularly in patients who have suffered multisystem injury; thus, it requires a systematic, reproducible, thorough approach. **A detailed patient medical history, a description of events surrounding the injury, a comprehensive physical exam, and laboratory and imaging adjuncts (as necessary) are required to ensure that all injuries are identified.**

In the awake and communicative patient, this can be relatively straightforward. Focusing on transparent communication can aid in establishing trust between the patient and the healthcare team. This trust often results in a more effective and efficient evaluative process. **However, in the trauma setting, patients often have an altered mental status because of brain injury, shock, intoxication, or medications. In these patients there is a high risk of missed injuries, which can have devastating consequences; thus, a high index of suspicion for injury is required.** The mechanism of injury and prehospital reports provide clues to injuries that may be uncovered during the secondary survey. Findings of the secondary survey can guide further management and interventions for optimal definitive care. Timely identification of injuries found in the secondary survey can improve patient outcomes and minimize complications.

MECHANISM OF INJURY

The mechanism of injury is associated with the patient's injury pattern and physiologic state. Understanding the mechanism of injury can assist in predicting potential injuries based on the force, direction, and type of insult. Broadly, mechanisms of injury can be divided into blunt, penetrating, and blast. Additional consideration must be given to thermal injuries and hazardous environments.

BLUNT INJURY

Blunt injury is caused by a forceful impact and can be caused by a broad range of sources, including falls, vehicle collisions, blows from objects or instruments, or interpersonal violence. Multiple injuries affecting different organ systems are possible.

For falls, pertinent details to consider include the height of the fall, secondary objects encountered during the fall, and orientation when contacting the ground. For motor vehicle collisions, information that can inform the clinician as to what injuries to anticipate includes the change in velocity, the principal direction of force (front, rear, or side impact), and the amount of intrusion into the passenger compartment, the position of the patient in the car, seatbelt use, and airbag deployment. Entrapment in or ejection from the vehicle or death of another vehicle occupant are other details that suggest a risk of severe injury.

Use of three-point seatbelt restraint and the presence of airbags in vehicles result in decreased morbidity from injuries. Airbags protect the head and upper torso from injury in adults. Children and small adults may sustain injuries related to airbag deployment, particularly to the head and chest. Use of a lap belt alone produces characteristic injuries that include Chance fractures of the spine, abdominal injuries, and head and facial injuries. Use of the shoulder belt alone can result in sliding out of the restraint (submarining) and possible ejection. **Motorcycle and bicycle collisions can result in more severe injuries, as these vehicles offer the rider little protection. Protective equipment such as helmets, boots, eye protection, jackets, pants, and gloves can decrease the severity of some injuries.** ■ **Table 14-1** outlines blunt trauma mechanisms and potential injuries associated with them.

■ **Table 14-1:Blunt Trauma Mechanism Considerations and Possible Injuries.**

Mechanism of injury	Other considerations	Possible associated injuries
Head-on crash		Facial injuries Lower extremity injuries Aortic injuries Cervical spine fracture Myocardial contusion
Rear-end crashes		Hyperextension injuries of the cervical spine Cervical spine fractures Central cord syndrome
Lateral impact crashes		Contralateral neck strain Cervical spine fracture Head injury Thoracic injuries Flail chest Pneumothorax Aortic disruption Diaphragm rupture Abdominal injuries: Spleen, liver or kidney Pelvic injuries Clavicle, humerus fractures
Rollover crashes	Greater likelihood of ejection Velocity changes	Crush injuries Compression spinal fractures
Ejection	Implies nonuse of restraints Higher mortality	Spinal injuries Places patient at greater risk of virtually all injuries
Windshield damage	Implies nonuse of restraints	Closed head injuries Facial fractures Skull fractures Cervical spine fractures
Steering wheel damage	Injuries mitigated with restraint use	Thoracic injuries Sternal fractures, rib fractures, flail chest Cardiac contusion Aortic injuries Hemo/pneumothoraces
Dashboard damage		Pelvic and acetabular injuries Hip dislocations
Pedestrian hit by vehicle	Pedestrians are unprotected Size of the vehicle can impact injury patterns Speed of vehicle May be run over creating crush injury	Head injury and craniofacial injuries Traumatic aortic disruption Abdominal visceral injuries Extremity fractures Tibia and fibula, knee injuries Femur fracture Pelvic fractures
Falls from heights	LD50 36-60 feet (11 to 18 meters)	Head injury Axial spine injury Abdominal visceral injuries Fracture pelvis or acetabulum Bilateral lower-extremity fractures Calcaneal fractures Renal and renal vascular injuries
Motorcycle collisions	Protective equipment can mitigate severity of injuries Injuries are worse with no helmet, boots, or leathers	Pelvic fractures Head injury Extremity fractures Soft-tissue injuries

PENETRATING INJURY

Penetrating trauma occurs when a foreign object pierces the body to create a wound, and the injury pattern depends upon the trajectory, location, and kinetic energy at impact. Stab wounds and bullet wounds are common examples of penetrating mechanisms of trauma. **For bullet-related injury, the proximity of the patient to the weapon, the missile trajectory, and the kinetics of the missile (muzzle speed and caliber) may predict the possibility of widespread radial tissue damage due to ballistic effect. In the case of stab wounds, the size and shape of the wound can vary. The external dimensions of the wound do not necessarily reflect the depth of penetration. Pertinent information to obtain from the patient or prehospital personnel include type of firearm, distance from firearm, number of shots heard, type of blade, length of blade, and amount of blood noted at the scene.** ■ **Table 14-2** outlines potential injuries associated with penetrating trauma.

BURNS AND HAZARDOUS ENVIRONMENTS

Burn injuries may occur in isolation or in conjunction with other blunt or penetrating mechanisms, and the severity of the burn depends on the depth, type, location, and total body surface area (TBSA) burned. Mechanisms resulting in burns include chemical, electrical, friction, radiation, or thermal injuries.

Patients may develop localized hypoperfusion injuries due to cold temperatures, commonly known as frostbite, or more profound injury resulting in hypothermia. Hypothermia, defined as a core body temperature less than 35°C or 95°F, can present acutely or chronically in patients exposed to cold, and it carries significant physiologic impact. It is important to recognize that aspects of the patient's history (wet clothes, vasodilation due to alcohol or drugs, decreased activity) may increase their chance of developing hypothermia or frostbite.

Inhalation injury and carbon monoxide poisoning can occur in cases of fires in enclosed spaces. Patients may require treatment for inhalation of other toxic byproducts of the combustion. **Transfer to a dedicated burn center is necessary in cases of partial-thickness burns greater than 10% TBSA; burns involving the face, hands, feet, genitalia, perineum, or joints; full-thickness burns; chemical burns; electrical burns; burns of pediatric patients; or inhalation injuries.** ■ **Table 14-3** outlines burn mechanisms and possible injuries.

A history of exposure to hazardous environments, including chemicals, toxins, and radiation, is important to obtain for two main reasons: these agents can produce a variety of pulmonary, cardiac, and internal organ dysfunctions in injured patients, and they can present a hazard to anyone in close proximity to the patient, including members of the healthcare team.

■ **Table 14-2: Stab and Bullet Wound Considerations and Possible Injuries.**

Mechanism of injury	Considerations	Possible injuries
Stab wounds • **Chest** • **Left thoracoabdominal** • **Abdomen** • **Extremity**	• Difficult to determine degree of injury based on external inspection; narrow weapons such as ice picks produce small external wounds that may extend into a cavity • Trajectory is difficult to determine	• Cardiac tamponade • Hemothorax • Pneumothorax • Left diaphragm, spleen, hemopneumothorax • Abdominal visceral injury with peritoneal penetration • Injury to muscles, nerves, veins, and arteries are possible; fractures are less common
Bullet wounds • **Truncal** • **Extremity**	• High likelihood of injury	• Trajectory determination from retained projectiles and external wounds help predict possible injuries • Neurovascular injury • Fractures • Compartment syndrome

■ **Table 14-3: Burn Injury Mechanism Considerations and Possible Injuries.**

Mechanism	Considerations	Possible injuries
Thermal burns	Circumferential eschars can result in respiratory compromise or compartment syndrome	Circumferential eschar on neck, extremity, or chest
	Occult trauma mechanism (jumping from building to escape fire)	Injuries associated with blunt trauma from fall from height
Electrical burns	High-voltage exposure and lightning strikes	Cardiac arrhythmias Rhabdomyolysis Myonecrosis/compartment syndrome
Inhalation burns	Enclosed space fires	Carbon monoxide poisoning
	May worsen overtime	Upper-airway swelling Pulmonary edema
	Cyanide inhalation	Cyanide toxicity
Chemical **• Acid** **• Alkali**	Concentration, amount, and duration of contact determine extent of injury	Partial- and full-thickness skin loss Systemic affects possible with some chemicals
• Petroleum products	May be difficult to remove and stop the burning process	

BLAST INJURY

Blast injury is a complex type of trauma that results from direct and/or indirect exposure to an explosion. It produces a range of injuries including burns as well as injuries to the lungs, extremities, brain, abdomen, and eyes. It includes multiple mechanisms. Primary blast injury results from high-pressure explosions and produces unique injuries including pulmonary barotrauma, tympanic membrane rupture, intestinal perforation, globe rupture, and traumatic brain injury (TBI). Secondary blast injury is caused by objects, fragments, and debris launched by an explosion, causing penetrating injury. Tertiary blast injury occurs from the blast wind launching a person's body into objects or the environment, producing penetrating or blunt injury. Quaternary blast injury comprises all other injuries caused by an explosion, including burns and toxic exposure. This topic is covered more thoroughly in *Chapter 24, Injury in Combat Zones and Austere Environments.*

HISTORY

The AMPLE mnemonic can be a useful tool to gather patient history:

- **Allergies**: Inquire about any known allergies, particularly to medications or substances that might be used during the patient's care.
- **Medications:** Obtain a list of current medications the patient is taking, including prescription, over the counter, and herbal remedies.
- **Past medical/social history**: Gather information about the patient's medical history, including chronic conditions, surgeries, hospitalizations, functional status, possible pregnancy, use of alcohol/illicit substances, tobacco use, housing status, occupation with associated hazards, and preferred language. Awareness of the social drivers of health aids the healthcare team with providing care during hospitalization and after discharge.
- **Last oral intake:** Determine when the patient last ate or drank, as this may influence the management of anesthesia or surgical interventions.
- **Events leading to injury**: Obtain details about the circumstances and mechanism of injury, which can help identify possible injuries and guide the physical examination. These details may also prompt the clinician to use patient safety screening questions if domestic violence or abuse is suspected, as seen in ■ **Box 14-1.**

Box 14-1: Questions to Ask Patients that Disclose Current Abuse to Immediately Assess for Safety.

	Assessment of Immediate Safety Screening Questions	No	Yes
1.	Are you in immediate danger?	○ **No**	○ **Yes**
2.	Is your partner at the health facility now?	○ **No**	○ **Yes**
3.	**a.** Do you want to home with your partner?	○ **No**	○ **Yes**
	b. Do you have to go home with your partner?	○ **No**	○ **Yes**
4.	Do you have somewhere safe to go?	○ **No**	○ **Yes**
5.	Have there been threats of direct abuse of the children (if s/he has children)?	○ **No**	○ **Yes**
6.	Are you afraid your life may be in danger?	○ **No**	○ **Yes**
7.	**a.** Has the violence gotten worse or is it getting scarier?	○ **No**	○ **Yes**
	b. Is it happening more often?	○ **No**	○ **Yes**
8.	Has your partner used weapons, alcohol, or drugs?	○ **No**	○ **Yes**
9.	Has your partner ever held you or your children against your will?	○ **No**	○ **Yes**
10.	Does your partner ever watch you closely, follow you, or stalk you?	○ **No**	○ **Yes**
11.	Has your partner ever threatened to kill you, him/herself, or your children?	○ **No**	○ **Yes**

COMPREHENSIVE PHYSICAL EXAMINATION

VITAL SIGNS

From the moment the patient arrives, assessing and reassessing the patient's vital signs is essential throughout the entire trauma resuscitation, and this should be carried on through the secondary survey. **The vital signs to be evaluated include blood pressure, heart rate, respiratory rate, oxygen saturation, and capnography if available. Alterations from normal values may indicate an untreated potential life threat, such as conversion of a simple pneumothorax to a tension pneumothorax or continued intra-abdominal bleeding. If this occurs, reassess beginning with the primary survey (xABCDE).**

EXTERNAL SIGNS OF TRAUMA

Whenever evaluating an anatomic region on the secondary survey, begin with inspection for external signs of trauma, including lacerations, bruising, deformities, or foreign bodies. Communicate with the patient the purpose of the evaluation and expose the areas you are assessing sequentially. External injury may indicate deeper injury that warrants further evaluation. When hemorrhage control has been required for external bleeding, reassess the area for continued control.

Tourniquets are now placed in the field by trained first responders and bystanders in addition to emergency medical services (EMS) personnel. **While tourniquets that remain in place for less than 2 hours have not been associated with a significant complication burden, there is increasing evidence that when left on longer, there is the potential for complications that may result in amputation.** The secondary survey is an ideal time to reevaluate the need for continued use of a tourniquet or conversion to pressure dressing.

The patient's vital signs should be normal before any conversion is undertaken. A patient who is in shock is not a candidate for tourniquet conversion. The tourniquet should have been in place for less than 6 hours, as release of tourniquets in place for longer than 6 hours risks reperfusion syndrome. Involve surgical consultants in the discussion whenever available. It is important to consider plans for both success and failure of conversion. Can the patient be managed at this facility, or will they require transfer to another facility to manage the bleeding if conversion fails? How long will it take to transfer the patient?

The extremity should be fully exposed and reevaluated to ensure there were no missed injuries. Tourniquet conversion requires time and wound-packing supplies. Have a new tourniquet available as well, in case the original fails and needs to be replaced. **Remove any old packing material in the wound. If there is no active bleeding, slowly release the tourniquet by unwinding the windlass, but do not remove it from the extremity. Once the tourniquet is loosened, inspect the wound for evidence of arterial bleeding. If none is seen, pack the wound and apply a pressure dressing for 3 minutes and continue to observe the wound. Leave the loosened tourniquet in place to facilitate rapid reapplication in the event bleeding recurs. If the wound remains hemostatic apply a pressure dressing. Patients may experience numbness, tingling, muscular weakness, and sensory changes that usually resolve rapidly after tourniquet removal. If bleeding recurs, reapply the original tourniquet. If that fails to control the bleeding, apply a second tourniquet above the first.**

Prepare the patient for emergency surgery to identify and treat the bleeding source if resources are available or prepare for transfer if they are not. **Time is of the essence, as tourniquets in place for more than 2 hours risk ischemic injury and limb loss. If the tourniquet has been in place for longer than 2 hours, the patient should be carefully monitored for metabolic abnormalities,**

arrhythmias, and development of renal failure. Reperfusion can produce rapid metabolic and hemodynamic changes that require prompt treatment and follow-up. Tourniquets in place for more than 6 hours will likely lead to ischemic tissue loss and possible amputation. The timing of conversion of these tourniquets should be determined in consultation with the trauma, vascular, and or orthopaedic surgeons. ■ Table 14-4 describes indications and contraindications to tourniquet conversion.

■ Table 14-4: Indications to Convert a Tourniquet or leave It in Place.

Indications for tourniquet conversion	Indications to leave tourniquet in place
• Alternative methods of hemostasis are readily available • Patient is not in shock • It is possible to monitor the wound for rebleeding • The tourniquet is not being used to control bleeding from an amputation	• A tourniquet is controlling bleeding from an amputation or near amputation or attempted conversion failed • Tourniquet has been in place for more than 6 hours

HEAD AND FACE

Examine the scalp, eyes, ears, nose, and mouth for signs of injury, such as lacerations, bruising, deformities, or foreign bodies. Palpate all bony structures of the head and face to assess for bony instability.

Examine the nose for drainage (serous or sanguineous), which may represent cerebrospinal fluid and indicate dural injury. **Nasal placement of gastric tubes should be avoided in patients with injury to the midface because of the risk of intracranial placement with injury to the cribriform plate.**

Nasal bone fractures with septal hematomas can lead to septal ischemia. Symptoms can include nasal congestion, difficulty breathing, and severe nosebleeds. Hematomas involving the cartilage of the ear can result in necrosis of the cartilage and may need to be decompressed.

Intraoral exam should assess for broken teeth, fractures, or instability. Hemotympanum and mastoid ecchymosis are signs of a potential skull base fracture.

EYES

Examination of the eyes includes inspection of the pupils for size, shape, and reactivity. Extraocular movement and visual acuity should be assessed. Visual acuity may be efficiently evaluated by asking the patient to read printed material or words on a piece of equipment. Ocular mobility should be included in the evaluation to exclude entrapment of extraocular muscles due to orbital fractures. Inspect for foreign bodies including contact lenses, and evaluate the globe for laceration, proptosis, periorbital ecchymosis, dislocation of the lens, or globe rupture, which may indicate direct ocular injury, intracranial hemorrhage, or retrobulbar hemorrhage. Visualization of corneal abrasions may be enhanced with long-wave UV light (Wood's lamp). Take care to evaluate the eyes early if facial edema is present and reevaluate if edema worsens.

NEUROLOGICAL EXAM

Neurological evaluation should begin with assessment of the patient's level of consciousness, memory, and Glasgow Coma Scale (GCS) score (see *Chapter 7, Disability: Neurological Assessment and Management*). Cranial nerves II–XII should be assessed with facial, ocular, oral, and shoulder movement and sensation, if clinically appropriate, **■ Table 14-5 describes a brief cranial nerve examination**. A comprehensive neurological exam includes motor and sensory evaluation of all extremities. **■ Figure 14-1 demonstrates the dermatomes and myotomes**. A change in status may indicate the need for further evaluation with imaging or surgical intervention. If a patient with a neurological injury clinically worsens, the adequacy of ventilation and perfusion (xABCDE) should be reevaluated. **Neurosurgical consultants should be informed of any clinical worsening. Timely transfer may be required when neurosurgical specialists are unavailable.**

■ Table 14-5: Cranial Nerve Functions and Testing Options.

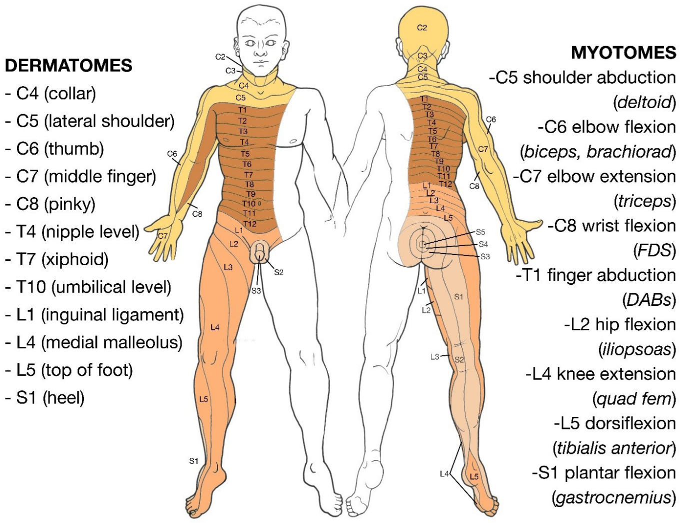
Cranial Nerve	Function	Assessment technique
II, III, IV, VI	Eye assessment	Visual acuity, tracking, pupil reactivity
VIII	Hearing and balance	Hearing, equilibrium, whisper words in each ear; assess for vertigo
VII, IX, X, XII	Speaking, smiling, and swallowing	Use a tongue pressure to stimulate gag reflex, have patient say ahh and swallow
V, VII, XII	Facial expression	Smile, frown, stick out tongue, jaw strength, corneal reflexes
XI	Shoulder shrug	Resist shoulder girdle raise
I	Smell	Identify a common scent like an alcohol pad, coffee, or soap; or from self-reported symptoms

■ Table 14-6: Muscle Strength Assessment Scale.

Score	Description
0	Total paralysis
1	Palpable or visible contraction
2	Active movement with gravity eliminated
3	Active movement against gravity
4	Moves against gravity and provides some resistance
5	Moves against gravity with normal resistance
NT	Patient unable to test because of pain, effort or contracture

Muscle grading scale NT, Not testable.

■ Figure 14-1: Dermatomes and Myotomes.



DERMATOMES

- C4 (collar)
- C5 (lateral shoulder)
- C6 (thumb)
- C7 (middle finger)
- C8 (pinky)
- T4 (nipple level)
- T7 (xiphoid)
- T10 (umbilical level)
- L1 (inguinal ligament)
- L4 (medial malleolus)
- L5 (top of foot)
- S1 (heel)

MYOTOMES

-C5 shoulder abduction (*deltoid*)
-C6 elbow flexion (*biceps, brachiorad*)
-C7 elbow extension (*triceps*)
-C8 wrist flexion (*FDS*)
-T1 finger abduction (*DABs*)
-L2 hip flexion (*iliopsoas*)
-L4 knee extension (*quad fem*)
-L5 dorsiflexion (*tibialis anterior*)
-S1 plantar flexion (*gastrocnemius*)

NECK

Patients with blunt trauma to the head, face, or neck should be presumed to have a cervical spine injury and be assessed for the need for ongoing cervical motion restriction. To examine the neck of a patient with a cervical collar, an assistant stabilizes the head with two hands while the examiner removes the front of the collar and performs the examination of the neck anteriorly and posteriorly. Examination of the neck includes inspection, palpation, and auscultation. Inspect for external signs of trauma, tracheal deviation, seatbelt sign, neck vein distension, or deformity, and palpate for subcutaneous emphysema, posterior midline tenderness, hematoma, or thrill of carotid arteries. Auscultate carotid arteries for the presence of a bruit, which may reveal a potential vascular injury.

Most vascular injuries occur with a penetrating mechanism, though a traction injury from a blunt mechanism may cause intimal disruption, dissection, or thrombosis. Penetrating injuries that violate the platysma should not be explored or probed. Surgical consultation is required if there is any physical exam finding concerning for vascular or aerodigestive injury (active bleeding, expanding hematoma, bruit, crepitus, airway compromise).

CHEST

Begin evaluation of the chest with inspection anteriorly and posteriorly for external signs of trauma. Assess for bruising, contusion, deformity, or paradoxical chest wall movement, which may be indicative of fractures to the ribs, clavicles, or sternum. A flail segment, identified with paradoxical chest wall motion, may indicate underlying pulmonary contusions. Auscultate bilaterally for the presence and quality of breath sounds and listen for distant or muffled heart tones. Auscultation of the chest can aid in identification of pneumothorax and hemothorax.

Palpate all areas of the chest, including the entire chest cage, clavicles, ribs, and sternum. Palpation can be painful in the presence of an underlying fracture, and contusions and hematoma may indicate underlying injuries. **Remember that pericardial effusions, pneumothoraces, and hemothoraces can expand with time and become clinically apparent with the development of increased respiratory effort, desaturation, tachycardia, and restlessness. Tension physiology or tamponade produces hemodynamic instability.**

ABDOMEN

Abdominal assessment begins with inspection for external signs of trauma, with particular attention for bruising, distension, penetrating injuries, or seatbelt sign. Seatbelt sign has been associated with hollow viscus injury and pancreatic injuries. Palpate each quadrant for tenderness, rigidity, or guarding, which may suggest internal injury or bleeding. A normal initial exam does not completely rule out an intra-abdominal injury. Abdominal pain can be referred from spine fractures or be related to soft-tissue injury. Surgical consultation should be obtained when intra-abdominal injury is suspected, and cross-sectional imaging with a CT scan can help identify intra-abdominal injuries that require observation or exploration.

PELVIS

Palpate the pelvis for tenderness to assess for potential pelvic fractures. Aggressive pushing and pulling to elicit evidence of instability is unnecessary, painful, and doesn't provide useful information. Ecchymosis over the flanks, iliac wings, pubis, labia, or scrotum is often present with pelvic fractures or retroperitoneal hematoma. Patients with significant pelvic fractures may have large-volume blood loss requiring aggressive resuscitation and a pelvic binder for stabilization. Patients with pelvic fracture are at risk for urethral and bladder injury. Blood at the urethral meatus and perineal ecchymosis are signs of potential injury.

PERINEUM, RECTUM, AND GENITALIA

The perineum should be examined for contusions, hematomas, lacerations, or blood at the urethral meatus, which may indicate genitourinary injury. A rectal examination is performed in select patients to assess for the presence of blood within the bowel lumen, integrity of the rectal wall, and quality of sphincter tone. Vaginal examination should be performed in patients who are at risk of vaginal injury, have blood in the vaginal vault, or have vaginal or perineal lacerations.

In addition, pregnancy tests should be performed on all females of childbearing age. These examinations frequently cause significant anxiety in alert patients. It is important to explain the purpose of the examinations and exactly what will be done. Minimize the number of people in the room when acuity allows, but always have a chaperone. Assure the curtains are closed and cover the parts of the patient that are not being examined.

EXTREMITIES

Inspect and palpate each extremity for lacerations, deformities, swelling, or tenderness, which may indicate fractures or dislocations. Assess the peripheral pulses, capillary refill, and sensation to evaluate circulation and nerve function. Evaluate range of motion at joints.

Fractured extremities should be reduced, realigned, and splinted using well-padded splints. See *Chapter 10, Musculoskeletal Trauma,* for further detail. **The neurovascular examination is repeated after splinting to ensure there has been no compromise. Patients with concurrent head or spinal cord injuries may have occult fractures that are difficult to diagnose on exam, and it may be necessary to perform frequent reexamination. Increased swelling, ecchymosis, or tenderness may indicate injury requiring further evaluation**. Orthopaedic consultation will guide the need for advanced imaging**. Maintain a high level of suspicion for injuries at risk for developing extremity compartment syndrome (long bone fractures, crush injuries, prolonged ischemia, and circumferential thermal injuries).**

BACK

Inspect and palpate the back and spine for tenderness, deformities, or step-offs, which may indicate vertebral fractures, dislocations, or spinal cord injury. Thoracic and lumbar fractures may be present without significant physical exam findings; thus, mechanism of injury must be considered to determine patients who should have cross-sectional imaging and x-rays. **Spinal motion is restricted with suspected injuries. Modified log rolling is used for movement, and the patient is positioned supine on a firm surface (not a backboard). Backboards, when used, are removed during the primary survey. If for any reason the patient remains on a backboard, remove it promptly. The head of bed can be elevated using reverse Trendelenburg positioning until instability of the spine is excluded**. Specialist consultation is required to determine the need for surgical intervention or advanced imaging.

ADJUNCTS TO SECONDARY SURVEY

During the secondary survey, additional specialized diagnostic tests are performed to aid in the assessment of the patient and to prioritize care. The decision to obtain adjunct testing should be based on the patient's clinical status, suspected injuries, and local resources. An ECG should be obtained if there is concern for blunt cardiac injury or underlying cardiac pathology. An ECG is useful in older adults who may have a medical cause for their trauma. Laboratory data are usually obtained during the primary survey. Results should be reviewed during the secondary survey and additional or repeat tests obtained based on physiology and suspicions for injuries.

IMAGING

Imaging studies play a crucial role in the secondary survey, helping confirm or rule out suspected injuries. The choice of imaging modality depends on the patient's clinical presentation, mechanism of injury, suspected injuries, and local resources.

X-RAY

X-ray is a useful imaging study to identify fractures and other injuries to the chest, abdomen, pelvis, and extremities. Chest x-rays and pelvis x-rays are included in the primary survey, though additional x-ray imaging may be performed for a variety of reasons. A portable x-ray can be performed efficiently at the bedside with minimal delay in patient care. In the setting of the secondary survey, a chest x-ray may assist in visualizing tubes or lines placed during the patient's assessment. These may include endotracheal tubes, central lines, chest tubes, or nasogastric/orogastric tubes. X-ray of the extremities can visualize fractures or dislocations, though some subtle fractures may not be visible initially. In cases of penetrating injuries such as bullet injuries, x-rays can aid in visualizing intracorporeal missiles and estimating trajectory. Although x-rays are an efficient and versatile tool, they do not visualize soft-tissue or ligamentous injuries. Spine injuries can be visualized by x-ray, although cross-sectional imaging is far more sensitive. CT scanning has supplanted x-ray in many centers where it is available.

ULTRASOUND

Ultrasound is a useful tool that can be used in numerous trauma situations when available. FAST and eFAST are expedient evaluation tools that are typically included in the primary survey. **These studies can be repeated when patients experience physiological change that may indicate bleeding or worsening pneumothorax or hemothorax**. Additional uses for ultrasound include fetal heart-tone monitoring in pregnant patients and echocardiography for patients with suspected wall motion or valvular abnormalities.

CT/MRI

Cross-sectional imaging, such as CT scans and CT angiograms, may help rapidly identify complex injuries of the head, neck, chest, abdomen, pelvis, or extremities that may not be apparent on physical exam or other imaging modalities. It is imperative to consider the clinical status of the patient and obtaining CT scans should not delay emergent operative intervention or transfer to an appropriate facility to address the patient's injuries if needed. Should a patient become unstable prior to transfer to the CT scan, the patient should be reassessed and resuscitated. Consult surgery if available to assess for the need for urgent surgical exploration or angioembolization.

In head injuries, noncontrast CT scans are routinely used in well-resourced settings to assess for TBI, intracranial hemorrhage, and facial or skull fractures. Dedicated images of the cervical, thoracic, and lumbar spine can aid in diagnosis of spinal fractures. If there is suspicion of extracranial carotid or vertebral arterial injury—as evidenced by cervical spine fractures, mandibular or skull base fractures, complex midface fractures, or neurological deficit inconsistent with head CT—a CT angiogram of the head and neck may be obtained. In circumstances where CT angiogram is not possible, duplex ultrasound may be used to assess suspected vascular injuries of the neck.

In patients with chest, abdominal, or pelvic trauma, CT scans can be used to diagnose a multitude of injuries to the vasculature, solid organs, abdominal viscera, or soft tissues. Intravenous, oral, or rectal contrast extravasation may identify vascular or hollow viscus injury, which should prompt further evaluation or consultation with a surgeon. When rectal contrast is used, explain the rationale for its use to the patient. When complex injuries are suspected or identified, one must consider if resources are available to manage the patient locally; if not, transfer is warranted.

Injuries to the extremities may require a CT scan if there is suspicion of complex fractures, joint involvement, or occult injuries not identified on plain radiography. If there is suspicion for vascular injury, CT angiogram may aid in diagnosis after comprehensive vascular exam. At times, it is most appropriate to proceed directly to the operating room for repair, and this decision should be made in conjunction with a surgeon.

MRI may be used selectively to evaluate for spinal cord, nerve, ligamentous, or soft-tissue injuries not well visualized on CT scans.

OTHER ASSESSMENT AND TREATMENT ADJUNCTS

Performing painful or potentially embarrassing procedures can create tension between the patient and the healthcare team. Providing assurances, using topical anesthetics or parenteral analgesics, and providing support can mitigate tensions.

NASO- OR OROGASTRIC TUBE

A gastric tube may be placed for gastric decompression or for identification of upper gastrointestinal bleeding. Gastric decompression decreases but does not eliminate the risk of aspiration, which is important in intubated patients. When placing nasogastric tubes in a patient who is awake, positioning of the patient is important, as placement may induce vomiting. Importantly, the tube is only effective if it is positioned correctly and connected to suction. Placement should be confirmed with an abdominal x-ray or aspiration of gastric contents. Blood in a gastric aspirate may indicate traumatic placement, swallowed blood, or actual upper gastrointestinal injury. **If a fracture of the cribriform plate is known or suspected, transnasal passage of an enteral tube should not take place.** Instead, orogastric placement will prevent intracranial passage of the tube.

URINARY CATHETER

Placement of a urinary catheter can assist in accurate measurement of urine output, bladder decompression, and identification of potential urologic injuries. **However, if on physical exam there is evidence of urethral injury (blood at the urethral meatus, perineal bruising), transurethral catheterization should not be attempted without a retrograde urethrogram.** Anatomic variability such as urethral strictures or prostatic hypertrophy may preclude placement of urinary catheters, and nonspecialists should not use excessive force when attempting placement. Urologic consultation should be requested early.

OTHER TREATMENTS

Patients with deep lacerations, extensive wound contamination, or open fractures will need antibiotic prophylaxis and wound washout. Lacerations should be debrided, repaired, and/or dressed. Tetanus immunization status should be ascertained, and vaccine administered based on the wound type and immunization history of the patient See ■ **Table 14-7** for tetanus immunization recommendations based on age and wound type. **Patients with fractures and other painful injuries should be given analgesics. Pain resulting from extremity fractures or dislocations is improved with reduction, realignment, and immobilization with well-padded splints.**

Reducing dislocations and realigning fractures, though ultimately diminishing discomfort, can produce intense acute pain. It is important to provide adequate analgesia while monitoring its effect on the airway, breathing, and circulation. Perform neurovascular assessment of the injured extremity before and after splinting or reduction of a dislocation. Poor pain control can result in respiratory compromise in patients with rib fractures. In addition to monitoring oxygen saturations, monitoring vital capacity via incentive spirometry can identify patients at risk for respiratory compromise. Pregnant patients who are Rh negative and have blunt-torso trauma require Rh immunoglobulin (RhoGam®) administration. Patients with TBI may require sedation, treatment of raised intracranial pressure with mannitol or hypertonic saline, and seizure prophylaxis.

■ **Table 14-7: Age-Based Tetanus Immunization Recommendations.**

Age-Based Tetanus Immunization Recommendations

Age (years)	Vaccination history	Clean, minor wounds	All other wounds
0 - 6	Unknown or up to date on DTaP series based on age	DTaP	DTaP TIG
	Up to date on DTaP series based on age	No indication	No indication
7 - 10	Unknown or incomplete DTaP series	Tdap and recommend catch-up vaccination	Tdap and recommend catch-up vaccination TIG
	Completed DTaP series AND ≤5 years since last dose	No indication	No indication
	Completed DTaP series AND ≥5 years since last dose	No indication	Td, but Tdap preferred if child is 10 years of age
11 + **(If pregnant, see footnote)**	Unknown or < 3 doses of tetanus toxoid containing vaccine	Tdap and recommend catch-up vaccination	Tdap and recommend catch-up vaccination TIG
	3 or more doses of tetanus toxoid containing vaccine AND < 5 years since last dose	No indication	No indication
	3 or more doses of tetanus toxoid containing vaccine AND 5-10 years since last dose	No indication	Tdap preferred (if not yet received) or Td
	3 or more doses of tetanus toxoid containing vaccine AND > 10 years since last dose	Tdap preferred (if not yet received) or Td	Tdap preferred (if not yet received) or Td

*Pregnant patients: As part of standard wound management care to prevent tetanus, a vaccine containing tetanus toxoid might be recommended for wound management in a pregnant woman if 5 years or more have elapsed since the previous Td booster. If a Td booster is recommended for a pregnant patient, healthcare providers administer Tdap. Source: https://www.cdc.gov/disasters/disease/tetanus.html. TIG, tetanus immune globulin.

REASSESSMENT

Periodic reexamination of the patient should be planned during the period of observation. Pay close attention to areas of abnormality previously identified and to new complaints, signs, or symptoms. Vital signs should be reassessed at frequent intervals as well. Abnormal laboratory values may require repeat testing. Patients with chest trauma may develop delayed pneumo- or hemothoraces. Subtle or dramatic changes in ventilation, respiration, or oxygenation may be seen on reevaluation. Evidence of bleeding from fractures, lacerations, or intra-abdominal or intrathoracic sources can present with expanding hematomas, increased pain, tachycardia, hypotension, or worsening metabolic acidosis. Patients with fractures can develop compartment syndrome and require neurovascular reassessment. Surgical consultation is required for prompt decompression.

SPECIAL POPULATIONS

Pediatric patients may be unable to provide background information or relay information regarding the circumstances of the injury or progression of symptoms. Geriatric patients may have cognitive or hearing challenges that make communication of historical information and changes in status difficult. Some people with cognitive disabilities may present similar challenges. Collateral information gathered from other sources, such as family or caregivers, prehospital personnel, or electronic medical records may aid in filling the gaps. In these patients, there is a high risk of missed injuries, which can have devastating consequences; thus, a high index of suspicion for injury is required. **Factors intrinsic to the patient, including age, medical comorbidities, and functional status, may affect their response to injury. There may be a need to make special accommodations that will allow more effective evaluation and treatment. Amplifiers for patients who are hard of hearing, translation for those with a different primary language or who are deaf, and family support in the resuscitation area are a few examples to consider.**

PRACTICE ENVIRONMENT CONSIDERATIONS

In resource-rich environments, cross-sectional imaging of almost all areas of the body has largely supplanted other modalities because it rapidly provides highly accurate and actionable information for the optimal management of the patient. However, very good outcomes can be achieved by utilizing less image-intensive protocols for diagnosis and management of injuries. Plain x-rays, diagnostic peritoneal lavage, and watchful serial evaluation by committed clinicians are excellent modalities in environments where cross-sectional imaging is either not available or is available in very limited capacity. Each hospital should develop its own protocols for how injuries to each of the body regions will be diagnosed and managed based on available resources in terms of imaging and specialists.

CHAPTER SUMMARY

The secondary survey is a vital component of the assessment of the injured patient. **While the primary survey identifies immediately life-threatening injuries, the comprehensive secondary survey ensures that all other injuries are identified. Vital signs are frequently reassessed to identify physiologic changes as rapidly as possible and facilitate rapid resuscitation. Imaging is an important adjunct to the physical assessment.** Cross-sectional imaging is valuable in diagnosing traumatic injury. Patients who are hemodynamically abnormal should be carefully reassessed for the need for surgical exploration versus CT imaging. Injuries evolve with time, and compartment syndrome, hemothoraces, and pneumothoraces require treatment when identified.

KEY LEARNING POINTS

- **The secondary survey starts when the primary survey is completed and the patient is hemodynamically stable or improved.**
- **An AMPLE history is obtained from patients who can provide it. In those unable to provide firsthand details, family, bystanders, and prehospital providers are relied upon.**
- **Vital signs are reassessed frequently. Changes may indicate alterations that require intervention.**
- **In hemodynamically normal patients with extremity tourniquets, assess the tourniquet's effectiveness and consider conversion to hemostatic dressing if the timing and situation are appropriate.**
- **A comprehensive physical examination will identify nonlife-threatening injuries.**
- **Provide tetanus immunizations, antibiotics, and analgesia as required.**
- **Consider the mechanism of injury in addition to the physiologic presentation to help identify the evaluation needed.**
- **A comprehensive evaluation will minimize the risk of delayed or missed injury evaluation.**
- **Injuries evolve over time, and the need for reassessment cannot be overemphasized.**

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15

Transfer to Definitive Care

OBJECTIVES

After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Define the term transfer to *definitive care* and understand its role in the ATLS algorithm
2. Recognize mechanisms of injury and specific injuries that may merit transfer
3. Describe interventions used to stabilize patients prior to transfer
4. Identify common potential modes of transportation and factors that determine which to use
5. Outline the information needed by an accepting facility
6. Describe the components of a pretransfer checklist

15

Transfer to Definitive Care

CHAPTER STATEMENT

Patient outcome is directly related to timely assessment, resuscitation, and progression to appropriate definitive care. Transfer to definitive care moves an injured patient to a setting with capabilities to manage their injuries definitively. This process could include moving a patient from a trauma resuscitation area to an operating room or transferring a patient from the emergency department of a nontrauma hospital to a trauma center or fully resourced facility. Transfer to definitive care is a planned, structured event.

INTRODUCTION

A key decision point for optimal care of the injured patient, according to ATLS® guidelines, is the transfer to definitive care, involving the movement of a patient to a care setting with appropriate resources to advance the management of specific injuries. This transfer promotes safe and appropriate care in another healthcare facility or internal unit in a trauma center (or fully resourced facility).

Recognizing when patient needs exceed capabilities in a facility or care unit is a trigger for early initiation of the transfer process between or within facilities. While the actual transfer to definitive care most often follows the Secondary Survey, it may occur during the Primary Survey, most often within a trauma center or fully resourced facility when exsanguinating hemorrhage requires rapid operative intervention, or within a critical access hospital when the best that the emergency department can do is sustain temporizing resuscitation and transfer the patient to a trauma center or other facility resourced with operating capabilities. **It is essential to know the injury care capabilities of your facility and to be ready for early transfer when injury needs exceed those capabilities.**

TRANSFER DECISION PROMPTS

Trauma systems focus on ensuring that injured patient needs are best matched to trauma centers with the capabilities to meet those needs in the shortest time possible.

Severely injured patients might initially be taken to a lower-level trauma center or a nontrauma hospital for Initial Assessment and management of life-threatening injuries. This initial destination decision is influenced by the severity of the injuries, patient location, and field triage determination. The goal is to sustain the patient's life in preparation for transfer to a higher-level trauma center. Criteria for transfer to a higher level of care include patient physiology, specific injuries or injury patterns, and patient characteristics. **When preparing to transfer a patient to another facility, medical care should focus on optimizing the patient for transport, identifying any physiological conditions that could worsen, and ensuring that body temperature remains normal.**

The main factor influencing the decision to transfer a patient is the initial hospital's ability to provide the necessary care for injuries. If the patient first arrives at a hospital that does not specialize in trauma care, such as a community or critical access hospital, plans for early transfer should be made and initiated while the patient is being resuscitated. **Preexisting regional transfer agreements can facilitate rapid patient transfer.**

Patients with injuries necessitating intervention during the primary survey warrant consideration for expedited transfer. Specifically, individuals presenting with the following conditions require advanced care levels and benefit from prompt transfer: airway compromise or at risk for airway loss, tension or open pneumothorax, clinical signs of shock, extremity fractures with vascular compromise (evidenced by active hemorrhage or distal ischemia), pelvic fractures with associated hemorrhage, significant physiological decompensation, or progressive neurological decline.

Furthermore, patients requiring surgical interventions that exceed the capabilities of the current facility, especially when immediate access to an operating room and a qualified surgical team are not available, should be rapidly transferred to ensure timely surgical management. **■ Table 15-1** lists some common indications for trauma patient transfer.

Patients with injuries that require critical care monitoring or specialty trauma care should be considered for early transfer as well. Urgent transfer should be considered for specific findings on Secondary Survey, including ophthalmologic injury, complex maxillofacial trauma, neck hematoma or crepitus, flail chest or multiple rib fractures with respiratory compromise, or hand injury. Patients with high-energy mechanisms or penetrating injuries to the head, neck, or torso warrant urgent transfer as well.

Certain populations with physiologic and anatomic nuances benefit from early transfer to a trauma center for management, including geriatric, pediatric, pregnant, and burn patients.

■ Table 15-1: Common Indications for Trauma Patient Transfer.

Common Injuries that Lead to Trauma Patient Transfer	
Type of Injury	**Common trauma transfer criteria**
Neurosurgical	• Open skull fracture • Lateralizing signs • Spinal cord injuries
Thoracic	• Major chest wall injury • Multiple rib fractures • Blunt aortic injury • Uncontrolled thoracic bleeding
Abdominal trauma	• High-grade solid visceral injuries • Pancreatic injuries • Intra-abdominal bleeding without OR • Transabdominal or pelvic bullet wounds
Extremity injuries	• Fractures with vascular injury • Open long-bone fractures • Complex long-bone fractures • Mangled extremities • Candidates for reimplantation of amputated limb
Pelvis	• Unstable pelvic ring fracture • Pelvic fractures with ongoing bleeding • Displaced acetabular fractures
Ocular injuries	• Globe injuries • Retrobulbar hematomas • Orbital fractures with entrapment
Maxillofacial trauma	• Bilateral mandible fractures • Open mandible fractures • Panfacial fractures
Specialty populations	• Patients with viable pregnancy (>24 weeks) with torso trauma
Burns	• Full thickness • Partial thickness >10% • Partial or full thickness involving the face, hands, genitalia, feet, joints, or perineum • Suspected inhalation • Combined trauma and burn • High voltage (>1000V) electrical or lightning strikes
Pediatrics	• Age <15 with major trauma • Burns
Comorbid conditions	• Advanced age • Cardiac or respiratory disease • Post-organ transplantation

***Note: This list is not exhaustive nor should every patient listed be transferred in all circumstances. Institutional capabilities are the driving forces.**

TRANSFER DESTINATION OPTIONS

Several factors determine the options for transferring patients, including the following: the existence and availability of transportation within a local or regional system; the locations of trauma centers (if they exist); and the types of hospitals providing broad specialty care (if designated trauma centers do not exist in the area). Preexisting transfer agreements set expectations and expedite transfers. When a formal trauma system exists, injured patients should be transferred from nontrauma to trauma centers and from lower-level trauma centers (III–V) to higher-levels trauma centers (I–II). When such a formal system is not established, creating protocols for transfer processes is still important.

In the US, trauma centers are classified into five levels, ranging from Level I, which acts as a comprehensive regional referral center, to Level V, which offers care through an emergency department only. Level I and II trauma centers are equipped with the most comprehensive resources for the definitive care of trauma patients.

Outside the US, the organization and designation of trauma centers can vary significantly, reflecting differences in healthcare systems, resources, and regional needs. For instance, some countries may have a different tier system or may integrate trauma care into general hospitals without a distinct trauma level designation. Nontrauma acute care hospitals, as they are known globally, are general medical facilities that treat various nontrauma surgical and medical conditions. Freestanding emergency departments, which can be affiliated with a hospital or operate independently, provide emergency services separate from hospital campuses. Critical access hospitals—a designation unique to the US—serve rural areas and offer essential healthcare and emergency services in locations far from other hospitals. Internationally, similar models exist to ensure healthcare access in remote areas, though they may operate under different names and criteria.

The initial receiving hospital should understand the medical services available in the region and the local rules for transferring patients. It should also set up standard agreements in advance to ensure the rapid and efficient transfer of patients who need specialized care. It is important to recognize when a patient's needs are beyond the local facility's capabilities as early as possible. **If resources are available and the necessary procedures can be performed, life-threatening injuries should be treated before transfer.**

Effective communication between the referring clinician and the receiving trauma surgeon/clinician is crucial. Challenges to this communication may arise from the referring clinician's less-frequent experience with severe injuries, which can lead to anxiety when managing such cases with limited resources. On the receiving end, there may be a lack of understanding about the resource limitations and the context of care at the referring hospital. **Referral is a call for help. A standardized communication tool, such as SBAR (situation, background, assessment, recommendations), helps organize the exchange of information, enhances awareness of the situation on both sides, and lays the groundwork for improved patient outcomes during transfer. ■ Table 15-2 uses the xABCDE framework with the SBAR acronym.**

■ Table 15-2: S xABCDE BAR Communication Tool.

S-xABCDE-BAR Communication Tool

Acronym	Intent	Information
S-xABCDE	**Situation-x-Airway-Breathing-Circulation-Disability-Exposure/ Environment**	• Referring clinician and facility • Name, age, gender, mechanism of injury • Indication for transfer • **x-**emergency hemorrhage control interventions (e.g., pressure, packing, or tourniquet) • **Airway:** assessment, intervention • **Breathing:** assessment, intervention • **Circulation:** assessment, intervention • **Disability**: assessment, intervention • **Environment/Exposure:** assessment, intervention
B	**Background**	• AMPLE history • Fluid/blood requirements • Medications (date and time) • Images • Reduction/splints
A	**Assessment**	**Current Status:** • Physiology • Response to interventions • Likely injuries
R	**Recommendation**	• Transport mode and capability • Transport interventions • Other necessary interventions

Using SBAR, the referring clinician provides a concise overview of the patient's situation, including the mechanism of injury, immediate concerns (xABCDE issues), interventions performed, and the reason for transfer. The patient's background, including relevant medical history (AMPLE history), fluid or blood requirements, imaging, and treatments administered (like pelvic binder application or fracture reduction/splinting), is shared. The assessment section covers the patient's response to interventions and current physiological state, while the recommendations include the preferred mode of transport, care capabilities during transport, and expected care needs enroute. The receiving surgeon/clinician then has the chance to ask clarifying questions, discuss transport parameters, and request documentation of the care provided before and during the transfer, including any procedures and imaging performed.

TRANSPORT MODES

INTERFACILITY

Transport methods for patients can be found in or around the local community, including ground vehicles, aircraft (both helicopters and airplanes), boats, and trains. The selection of a transport mode is influenced by multiple factors: the level of care the transport can provide compared to what the patient requires, the geographic location, current/emerging weather conditions, the distance to be covered, and the impact on local resources (for example, the reduced availability of ambulances for other emergencies). The two most frequently used methods of moving patients between facilities have their own specific needs: ground transport requires accessible and passable roads, while helicopter transport needs a suitable place to land and depends heavily on acceptable weather conditions. Some trauma centers or equivalent facilities strategically station ground and air ambulances across a region to be ready for rapid deployment.

Within each mode of transport, there are different levels of medical support available, ranging from basic to advanced life support up to specialized care transport. Basic life support ambulances are staffed with emergency medical technicians (EMTs) and are equipped to provide noninvasive treatments, such as CPR and oxygen, with a limited range of medications and without the capacity for procedures like intubation or surgical interventions.

Advanced life support ambulances are operated by paramedics capable of performing invasive procedures and administering a wider range of medications, including whole blood, packed red blood cells, and plasma. Specialty care transport services are designed for critical care or burn care and offer a higher level of medical expertise and equipment for severe clinical conditions.

INTRAFACILITY

In a trauma center or equivalent facility, transport between settings of care involves monitoring of vital signs and ongoing interventions by a dedicated multidisciplinary team, which may include surgeons, emergency medicine physicians, anesthesiologists, orthopedists, advanced practice practitioners, nurses, and respiratory therapists. **Care must be taken to ensure that lines, tubes, and splints are secured to the patient and do not become displaced or dislodged with necessary movement.**

PRIORITIES FOR PATIENT TRANSPORT READINESS

Preparation for transfer begins with facility preparedness and continues through early recognition of patient needs exceeding facility capabilities. Facilities must be familiar with regional capabilities and local guidelines for transfer. Preexisting standard transfer agreements should be in place to facilitate rapid transport of appropriate patients. **Imaging that does not bear on the immediate treatment of life-threatening injuries should be avoided.**

In preparation for a safe transfer, patients should be resuscitated to an acceptable physiology, with further interventions aimed at stabilizing physiology and injuries while preventing secondary injury. Before transfer, it is essential to reevaluate resuscitative measures for x, airway, breathing, circulation, disability, and exposure to ensure they are secure, functioning properly, and producing the desired physiological outcomes. **Anticipating the worsening of injuries is crucial; therefore, preventive measures like intubating patients at risk of airway loss or decompressing a pneumothorax that could expand should be undertaken. All medical devices, such as tubes, lines, and splints, must be checked to confirm they are working correctly and securely attached to avoid dislodgement during transport.** A checklist can be useful for ensuring that the smallest details are not forgotten. (**■ Table 15-3 ATLS Transfer Checklist is an example of such a checklist.**)

■ Table 15-3: ATLS Transfer Checklist.

ATLS Transfer Checklist	
1. x – Control Life-Threatening External Hemorrhage	
○	Check for exsanguinating or significant external hemorrhage (pooling blood, strike-through on dressings, bleeding distal to tourniquet).
○	Apply direct pressure, tourniquet, or hemostatic dressings as needed.
2. A – Airway with Cervical Spine Protection	
○	Assess airway patency (altered sensorium, facial/neck/chest trauma, multisystem trauma).
○	Verify that cervical spine protection (e.g., C-collar) is in place.
○	Check if advanced airway is in place and functioning.
○	Provide airway support if necessary (e.g., intubation, airway adjuncts).
3. B – Breathing and Ventilation	
○	Assess for significant pneumothorax or hemothorax (FAST, CXR, clinical signs).
○	Ensure chest tube is in place and functioning if applicable.
○	Confirm pulse oximeter is placed and functioning.
○	Verify that respiratory status is stable if pneumothorax was treated without a tube.
4. C – Circulation with Hemorrhage Control	
○	Ensure large-bore IV access is in place and functioning.
○	Assess if ongoing resuscitation is needed (fluids, blood products).
○	Reassess for internal bleeding (e.g., FAST, clinical assessment).
○	Ensure pelvic binder is properly positioned and tightened if applicable.
○	Confirm fractures are splinted and splints are secure.
○	Administer necessary fluids or blood products if required.
5. D – Disability (Neurological Status)	
○	Reassess neurological status (Glasgow Coma Scale, pupil checks).
○	Reassess neurovascular function of all extremities.
○	Ensure spinal motion restriction is in place (C-collar, flat positioning, modified log roll if needed).
6. E – Exposure/Environmental Control	
○	Fully expose the patient to assess for hidden injuries.
○	Assess for hypothermia.
○	Apply warming measures if necessary (blankets, warmed fluids).
Secondary Survey and Additional Considerations	
○	Review and reassess identified injuries from Primary and Secondary Surveys.
○	Consider interventions to prevent progression of identified injuries.
○	Confirm review of patient care preferences and goals of care.
○	Ensure pain has been assessed and analgesics administered.
○	Verify the function and security of all tubes and lines.
○	Ensure documentation and imaging are bundled and ready for transfer.
○	Confirm plan of care is discussed with patient, family, receiving team, and specialists.

In preparation for transport, it may be necessary to employ damage control resuscitation strategies. These includes obtaining reliable vascular access and administering controlled fluid volumes to temporarily stabilize the patient and achieve acceptable vital signs, especially when definitive hemorrhage control is not possible. If available, blood products should be transfused as needed to sustain physiological stability and support coagulation, depending on the degree of shock. Address hypothermia by warming the patient and implementing measures to maintain normal body temperature during transport.

Interventions to manage or treat any conditions that pose an immediate threat to life must be performed. For soft-tissue injuries, perform rapid irrigation, packing, and wrapping and give antibiotics and tetanus prophylaxis without delaying transfer. The patient's potential risk to self or others should be assessed, and appropriate protective actions taken. All documentation of evaluations, management actions, diagnostic tests, and images should accompany the patient, without wasting time copying nonessential paperwork.

Handoff to the transfer team is best accomplished with a standard tool, such as SBAR. Critical information must be communicated with clarity, brevity, and consistency. Information exchange between referring and receiving physicians guides care before and during transport. Critical information includes demographics, mechanism of injury, identified injuries (broadly), timeline of interventions following the primary and secondary survey, current status (physiology and interventions), anticipated care enroute, and preferred transport option.

Interfacility transfers should be reviewed through a performance improvement process. A regional trauma system approach to performance improvement of patient transfers—inclusive of EMS, the sending facility, and the receiving trauma facility—is ideal.

TRANSFER DELAY

When transfer is delayed, goals shift from preparation for early transfer to continuing resuscitation, stabilization, and, in some cases, damage control operations for emergent injuries when capabilities exist. Prolonged care at the initial facility might be necessary under conditions that impede transport, such as bad weather, ground barriers, and lack of available transport vehicles. Prolonged care may also be necessary in a mass casualty incident with critical bed shortages at receiving facilities (e.g., during the COVID-19 pandemic). **Transfer should not be delayed obtaining imaging or perform evaluations that do not impact the patient's physiologic status.**

Triage priorities for intervention and transfer in mass casualty incidents should be in place to guide decision-making for transfer. The triage goal is to identify and treat critically injured casualties within a large population of noncritically injured casualties. Facility transfer protocols should have caveats for mass casualty incidents. When fully resourced centers become overwhelmed, tiered-resource use may allow transfer of patients with injuries that don't pose an immediate life threat to facilities that don't routinely care for injured patients but have the capability to do so. Examples include patients with penetrating extremity injuries, nontorso ballistic injuries, orthopaedic injuries, or amputation.

SPECIAL CONSIDERATIONS

Patients for whom transfer may not align with their expressed care preferences, such as those in hospice or where transfer would not alter the inevitable progression towards mortality due to the severity of injuries, warrant special consideration. For these patients, prioritizing comfort care may be more appropriate. Whenever feasible, a discussion should occur with the patient regarding their injuries, the goals of transfer, and end-of-life preferences before making a transfer decision. In cases involving unconscious patients, it is imperative to make efforts to contact family members or surrogates who can represent the patient's wishes and values before proceeding with the transfer. This approach promotes care decisions, including the choice to transfer, that are in harmony with the patient's own goals and care expectations.

CHAPTER SUMMARY

The decision to transfer for definitive care may be between facilities or within a trauma or equivalent center. Depending on patient physiology and injury, the transfer process should be initiated upon recognition that the patient's needs are greater than the facility's capabilities. **The actual transfer may occur following the secondary survey, though for patients with exsanguinating injuries, transfer may happen even with ongoing resuscitation.** Within the regional trauma system, all trauma transfers should be reviewed through a performance improvement process. Even when a formal trauma system has not been established, such an oversight process should be put in place.

KEY LEARNING POINTS

- **Patient injuries relative to facility capabilities and goals of care determine the need for transfer.**
- **Determination of the appropriate transport mode requires assessment of likely transfer time, geographic and weather conditions, and patient needs en route.**
- **Readiness for transfer to definitive care requires awareness of facility capabilities and receiving trauma center options within the regional trauma system.**
- **When patient injuries exceed facility capabilities, do not delay transfer for secondary survey imaging (e.g., CT scan, extremity radiographs).**
- **Review the patient's expressed goals of care before transfer.**
- **At a trauma center, consider direct transfer to the operating room for exsanguinating patients (when protocols for this exist).**

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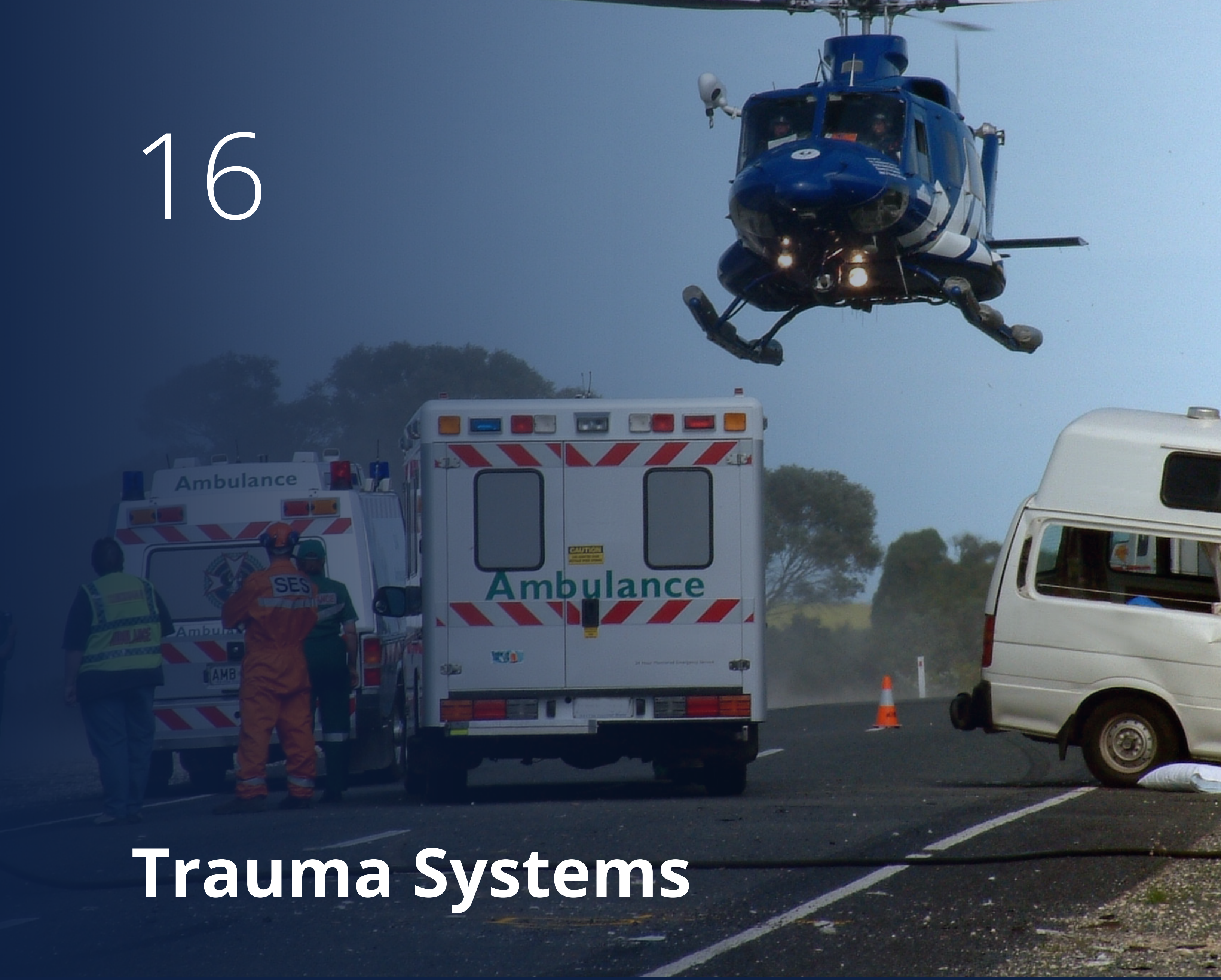
SECTION II

Trauma Systems and Patient-Centered Care

Chapter 16: Trauma Systems **243**
Chapter 17: Triage and Disaster Management **249**
Chapter 18: Injury Prevention **257**
Chapter 19: Trauma-Informed Care and Social Determinants of Health **269**
Chapter 20: Communicating Serious News in the Acute Trauma Setting **279**



16

Trauma Systems

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Explain the importance of a systems approach to injury care
2. List the benefits of trauma systems
3. Describe the different components of a trauma system
4. Describe how a trauma program should be able to demonstrate effective patient's safety and trauma care
5. Understand how local and regional factors affect implementation

16

Trauma Systems

CHAPTER STATEMENT

Trauma systems are a vital component of the healthcare system, providing coordinated, comprehensive care to injured patients with the goal of reducing mortality and morbidity, as well as improving quality of life following trauma. The primary goal of a trauma system is to have the right patient get the right care at the right time.

INTRODUCTION

Injury is a public health problem of enormous magnitude, whether measured by years of productive life lost, prolonged or permanent disability, or financial cost. Globally, published work demonstrates it is the most common cause of death and disability for those under 44 years of age. Implementation of a regional trauma system has resulted in significant improvements in trauma care and a reduction in mortality worldwide. A study published in the *Journal of Trauma and Acute Care Surgery* demonstrated that patients treated at trauma centers had a 25% lower risk of death compared to those treated at nontrauma centers.

Knowledge of trauma systems is essential for anyone involved in the care of trauma patients, from healthcare providers to policymakers, as it can help improve the quality of care and outcomes for injured patients.

PRACTICE ENVIRONMENT CONSIDERATIONS

DEFINITION AND GOALS OF TRAUMA SYSTEMS

A trauma system is an organized, coordinated effort in a defined geographic area that delivers the full range of care to all injured patients regardless of race, ethnicity, gender, religion, age, or ability to pay and is integrated with the local public health system. The primary goal of a trauma system is to have the right patient get the right care at the right time. Within a geographic area, a trauma system encompasses prehospital notification and treatment, acute hospital care, and access to rehabilitation services when needed. Trauma systems require collaboration between emergency medical services (EMS) personnel and other stakeholders to provide coordinated care to trauma patients.

BENEFITS OF IMPLEMENTING A TRAUMA SYSTEM

There are several key benefits to implementing a trauma system:

- Rapid access to prehospital care
- Specialized treatment at designated trauma centers with the necessary expertise and resources
- Coordination of care across different clinicians, ensuring that patients receive appropriate treatment and follow-up
- Enhanced collaboration between healthcare clinicians, leading to improved communication and care coordination
- Improvement of outcomes—**the effectiveness of trauma systems can be measured by several outcomes, including mortality, morbidity, disability, and quality of life.** Some studies have shown that trauma systems can also improve functional status and return to work following trauma
- Overall healthcare cost reduction by providing prompt and efficient care and reducing the length of hospital stay

REGIONAL TRAUMA SYSTEMS: OPTIMAL ELEMENTS, INTEGRATION, AND ASSESSMENT

Organized approaches within single facilities to care for victims of severe injury have repeatedly demonstrated improved outcomes, an observation that has led to the development of the trauma center verification process. **Regionalized trauma systems should have a process for triaging patients,** ensuring that a patient gets to the level of trauma care that matches their injury severity and resulting in improved outcomes.

The care of injured patients requires a systems approach to ensure optimal care. A systematic approach is necessary within a facility; however, no individual trauma center can do everything. A systems approach is necessary within an entire community regardless of its size.

The term "inclusive trauma system" is used for this all-encompassing approach, as opposed to an "exclusive" system, which refers only to the major trauma center.

TRAUMA SYSTEM COMPONENTS

A trauma care system includes key elements: injury surveillance and prevention, emergency medical services, prehospital care and transportation, acute hospital care, rehabilitation, disaster preparedness, education, and research.

INJURY SURVEILLANCE AND PREVENTION

Traditionally, prevention efforts have focused on education, enactment, enforcement, and environmental modification. Part of every effective injury prevention effort is a focus on proximate causes. Many injuries have alcohol and drug use as an important contributing factor. Screening and brief intervention for alcohol use are required of all verified trauma centers in the US. Access to firearms is another important root cause of injury. Socioeconomic, cultural, environmental, and engineering factors should also be considered.

Trauma systems must have an organized and effective approach to injury prevention, must prioritize those efforts based on local trauma registry and epidemiologic data, and, perhaps most important, must partner with injury prevention experts and resources in the community. This collaboration leads to an exchange of data and ideas that allows better analysis of the problem and its solutions. Geographic information systems have also proven effective in studying intentional injury in various communities. They can successfully identify high-risk areas and factors associated with intentional injuries as targets for prevention.

Vital records and medical examiners' reports describing causes of death, along with the data available from local and state police, help identify the incidence of injuries and high-risk behaviors. These reports identify injuries in a manner that is often not available using the trauma registry (see *Chapter 18, Injury Prevention*).

EMERGENCY MEDICAL SERVICES

The goals of the EMS are to prevent further injury, initiate resuscitation, and provide safe and timely transport of injured patients. High-quality, consistent emergency care requires that all prehospital personnel in a trauma region understand the trauma triage criteria and destination protocols, treatment protocols, transportation alternatives, and capabilities of trauma facilities in their geographic region.

TRAUMA CARE FACILITIES

Essential to the development of a trauma system is the designation of definitive trauma care facilities. The trauma system is a network of definitive care facilities that provides for all injured patients. To achieve the goal of decreasing the burden of injury, a trauma system needs to develop a network of acute care facilities, personnel, and organizational entities that function in an organized and coordinated manner in a geographic area. These acute care facilities and their healthcare clinicians are essential system resources that must be active and engaged participants.

TRAUMA CENTERS

In the US, trauma centers are categorized according to the depth of their resources, where Level I trauma centers have the most resources and Level IV the fewest.

LEVEL I

A Level I facility is a regional resource trauma center that is a tertiary care facility central to the trauma care system and generally serves large cities or densely populated areas. Ultimately, all patients who require the resources of a Level I center should have access to it, either directly or through efficient transfer processes. This facility must have the capability of providing leadership and total care for every aspect of injury, from prevention through rehabilitation. In its central role, a Level I center must have adequate depth of resources and personnel. This responsibility includes all hospitals caring for injured patients in their regions.

Because of the significant resources required for patient care, education, and research, most Level I trauma centers are university-based teaching hospitals. Other hospitals willing to commit these resources, however, may meet the criteria for Level I recognition. Medical education programs include residency program support and postgraduate training in trauma for physicians, nurses, and prehospital providers. Research and prevention programs, as defined in this document, are essential for a Level I trauma center.

To ensure adequate experience and expertise, designation as a Level I trauma center requires that a certain volume of injured patients to be admitted each year, including the most severely injured patients from the system. In addition, certain injuries that occur infrequently should be concentrated in this special center to ensure that these patients are properly treated and studied. A Level I trauma center must admit at least 1,200 trauma patients yearly or have 240 admissions with an Injury Severity Score of more than 15.

LEVEL II

A Level II trauma center can be an academic institution or a public or private community facility located in an urban, suburban, or rural area. A Level II trauma center is expected to provide initial definitive trauma care, regardless of the severity of injury. In densely populated areas, a Level II trauma center may supplement the clinical activity and expertise of a Level I institution. In systems with lower-population densities, a Level II trauma center often serves as the lead hospital.

Level I and Level II trauma centers are expected to be clinically equivalent except for very complex, specialized injuries such as replantation. However, depending on geographic location, patient volume, personnel, and immediate availability of resources, a Level II trauma center may not always be able to provide the same level of comprehensive care as a Level I trauma center.

LEVEL III

A Level III trauma center serves communities that do not have immediate access to a Level I or II institution. A Level III trauma center should have the capability to initially manage most injured patients and have transfer agreements with a Level I or II trauma center for seriously injured patients whose needs exceed the facility's resources. A Level III trauma center must have continuous general surgical coverage.

Level III trauma centers can provide prompt assessment, resuscitation, emergency operations, and stabilization and can arrange for transfer to a facility that can provide definitive trauma care when needed. Well-trained emergency department physicians and general surgeons are required in a Level III facility. In remote areas, a Level III trauma center may take on the responsibility for education and system leadership. Level III trauma centers are generally not appropriate in an urban or suburban area with adequate Level I and/or Level II resources.

LEVEL IV

Most Level IV hospitals are in rural locations and usually supplement care within a larger trauma system. Level IV trauma facilities provide advanced trauma life support before patient transfer in remote areas where no higher level of care is available. Level IV facilities provide initial evaluation and assessment of injured patients, but most patients will require transfer to higher-level trauma centers. A Level IV facility must have 24-hour emergency coverage by a physician or midlevel clinician.

A Level IV trauma facility should be an integral part of the inclusive trauma care system, and participation within the larger trauma system is essential. As with Level III trauma centers, treatment protocols for resuscitation, transfer protocols, data reporting, and participation in system performance improvement are essential. Also, it is essential for a Level IV facility to have the involvement of a committed physician who can provide leadership and sustain the affiliation with other centers.

TRAUMA CARE COORDINATION

Effective trauma systems must have a lead hospital. These lead hospitals should be the highest level available within the trauma system. In most trauma systems, a combination of levels of designated trauma centers will coexist with the other acute care facilities that should also be formal members of the trauma system caring for injured patients of lesser acuity. These institutions must provide data and participate in performance improvement.

REHABILITATION

The rehabilitation of injured patients should begin on the first hospital day. Acute care should enable optimal functional recovery. **The ultimate goal of trauma care is to restore the patient to preinjury status**. Not only is this effort best for the patient; it also is less costly.

DISASTER PREPAREDNESS

Trauma systems are at the vanguard of disaster preparedness. Responses to prior mass casualty events have helped some trauma systems prepare for future disasters without overwhelming any individual trauma center. Disaster response planning is a complex endeavor. A hospital disaster plan begins with a hazard vulnerability analysis. This analysis involves a projection of the most likely threats—natural and human-caused, intentional or accidental—to the hospital and surrounding community.

DATA COLLECTION

A trauma registry is a disease-specific database composed of uniform data elements that describe the injury event, demographics, prehospital information, diagnosis, care, outcomes, and costs of treatment of injured patients. The foundation for evaluation of a trauma system is the establishment and maintenance of a trauma registry.

PERFORMANCE IMPROVEMENT

Quality improvement programs are an integral part of a mature trauma system. Trauma quality improvement programs have consistently been shown to improve the process of care, decrease mortality, and decrease the costs of implementing either a regional trauma system or a dedicated hospital-based trauma service.

A trauma center should provide safe, efficient, and effective care to the injured patient. It requires the authority and accountability to continuously measure, evaluate, and improve care (performance improvement). **These essential elements of a trauma program are commonly known in the US as a trauma performance improvement and patient safety (PIPS) program.** Trauma programs should be able to demonstrate effective patient safety activities that minimize the incidence and impact of medical errors and maximize recovery when errors do occur.

EDUCATION AND OUTREACH

RESEARCH AND SCHOLARLY ACTIVITY

Research and scholarly activity are some of the capabilities that distinguish the highest-level trauma centers from other trauma centers. Research, the process of advancing knowledge, is essential to optimize the care of injured patients.

PUBLIC EDUCATION

Trauma centers must become important community and regional resources. These centers must turn into sources of information, expertise, and public safety leadership in the treatment of major injury. Trauma centers and regional systems also stand to improve their services by bringing the community voice to the table in order to understand the needs and social drivers that impact risk, access to care, and postdischarge quality of life. **It is important that trauma center professionals participate in public education** to enhance prevention efforts, disseminate awareness of trauma systems and how to access them, and build support for public policy change.

First-aid courses and CPR (airway skills) classes teach basic management principles to laypeople. Good educational programs to teach simple lifesaving and limb-saving skills and how to avoid harming injured patients are needed to enhance any trauma system. The ACS Stop the Bleed® program has prepared nearly 4 million people worldwide on how to stop bleeding in a severely injured patient.

PROFESSIONAL EDUCATION AND TRAINING

Principles of trauma care are introduced in medical school, nursing school, prehospital provider programs, and other allied health training programs. The Advanced Trauma Life Support® (ATLS®) Course and similar educational programs have become basic trauma educational endeavors for healthcare professionals. The Trauma Evaluation and Management (TEAM)® course was initially developed to introduce the concepts taught in ATLS to medical students, but it has now been redesigned to meet the needs of a much larger target audience.

It is also desirable that surgeons involved in the care of injured patients participate in advanced trauma skills training. Although this advanced training can be accomplished through a variety of methods, the ACS Committee on Trauma (COT) has developed two formal courses that may be used to meet this need. These are the Advanced Trauma Operative Management (ATOM®) and Advanced Surgical Skills for Exposure in Trauma (ASSET®) courses, which are complementary courses teaching advanced principals of operative trauma management and exposure.

TRAUMA SYSTEMS ASSESSMENT AND VERIFICATION

Trauma center verification validates the presence of resources, structure, and processes. While a trauma center verification visit focuses on *hospital-level* criteria, a trauma system consultation is broader in scope, examining the integration of trauma system components for a *state*, *regional*, or *county-level system of care*.

TRAUMA SYSTEMS WORLDWIDE

The degree to which trauma system principles have been implemented varies widely across the globe. In many places, the lack of resources and infrastructure for healthcare are key limiting factors, but a strong trauma system also requires support of the healthcare governance structure, along with the laws, rules, regulations, and oversight necessary to enable system operations. As noted by Mock et al, when comparing trauma systems in Ghana (low-income country), Mexico (middle-income country) and the United States (high-income country), mortality due to trauma decreased as the income level of a country increased.

In trauma systems development, decisions must be made as to the extent to which limited resources should be allocated to specific programs. In Mock's study, the majority of deaths occurred in the prehospital setting regardless of the economic level of a country, indicating the importance of injury prevention at all levels. Even in high-resource areas with sophisticated healthcare facilities, there is often a lack of the policy support necessary to implement and maintain a robust system. Competition between healthcare facilities and division of care between public and private systems can also present challenges to system development.

In order to be successful, efforts to develop a systems approach to injury care must take into account the resources available, the governance structure, and the political support for injury care in a particular region. Though the specific approach to system development will be unique, there are global principles that can help provide guidance. Examples include the World Health Organization (WHO) tools for strengthening emergency care systems, as well as the essential elements for trauma systems developed by the ACS COT. These principles can be prioritized based on resource availability, existing models of care, and degree of governmental engagement.

HIGHER RESOURCE ENVIRONMENTS

There are many examples of high-functioning trauma systems that operate in high-resource environments through the world. Key elements common to such systems include strong policy support, governance, and funding arising from local, regional, or national agencies and ministries. These systems typically have well-established standards that define various levels of trauma center along with a verification program to ensure that facilities maintain these standards. EMS are governed by well-established standards that determine field identification of trauma patients, guidelines for hospital destination, ambulance equipment levels, and EMS provider training. These systems also have robust processes for data collection, data sharing, and system-level quality improvement.

In most cases, the regional trauma system will have not only areas of strength but also areas of weakness, and efforts to drive system development and improvement should be maintained. In high-resource settings, the system often arises from a network of trauma hospitals. Rigorous standards for trauma center resources and function are attainable and should be established. EMS systems are often sophisticated but may lack specific guidelines for identification and distribution of trauma patients based on resource needs. Data sharing and system-level quality improvement often face significant limitations based on competition and distrust between hospital systems. Finally, even though the patient care aspects of the health system may have adequate funding, sustainable funding for system-level operations, including data collection and analysis, is frequently insufficient. The path forward generally involves identifying areas of weakness and seeking to apply rigorous standards that have shown benefit in successful systems.

RESOURCE-RESTRAINED ENVIRONMENTS

In much of the world, the healthcare system is severely limited by the availability of resources and may struggle to meet even the basic care needs of the population. In such circumstances, efforts to improve the care of injured patients must take such realities into account, but the fundamental principles still apply. Policy-level support and a governance structure for injury care are equally critical and may be relatively easier to achieve than in more economically profitable environments, in which the drivers of the overall health system are more complex.

The establishment of standards for trauma center resources and processes is an essential step that is even more critical in regions where there is no preexisting network of sophisticated healthcare facilities. These standards must be rational, locally relevant, and aim to set an attainable level of function rather than simply adopting standards from higher-resource settings that may not be achievable. Progress is made by incrementally raising the bar. The same approach must also be applied to EMS systems, defining standards, operational strategies, and improvements that are adapted to local circumstances but follow the underlying principles that govern care regardless of resource availability. It is necessary to develop and prioritize methods for basic data collection and analysis, even in the most limited settings, as data are essential to guide future change.

CHAPTER SUMMARY

A trauma system is a coordinated effort in a defined geographic area that is integrated with the local public health system and delivers care to all injured patients. The primary goal of a trauma system is to have the right patient get the right care at the right time. Implementation of regional trauma systems has resulted in significant improvements in trauma care and a reduction in mortality worldwide. It's important to consider the unique context of each region, including its infrastructure and resource availability, to tailor the strategies accordingly. A comprehensive assessment of regional needs, existing assets, and potential barriers is crucial for designing effective interventions to improve care for all patients in the region.

KEY LEARNING POINTS

- **Trauma systems are a vital component of the healthcare system with the aim of reducing mortality and morbidity, as well as improving quality of life following trauma.**
- **A trauma system is an organized, coordinated effort in a defined geographic area that delivers the full range of care to all injured patients and is integrated with the local public health system.**
- **Regionalized trauma systems should have a process for triaging patients, ensuring that a patient gets to the level of trauma care that matches their injury severity and resulting in improved outcomes.**
- **A trauma system includes key elements: injury surveillance and prevention, emergency medical services, prehospital care and transportation, acute hospital care, rehabilitation, performance improvement, education, and research activities.**
- **Quality improvement programs are an integral part of a mature trauma system. Trauma quality improvement programs have consistently been shown to improve the process of care, decrease mortality, and decrease the costs.**
- **The degree to which trauma system principles have been implemented varies widely across the globe. In many places, the lack of resources and infrastructure for healthcare are key limiting factors, but a strong trauma system also requires support of the healthcare governance structure, along with the laws, rules, regulations, and oversight necessary to enable system operations.**

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17

Triage and Disaster Management

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Differentiate the terms: mass casualty event (MCE), mass casualty incident (MCI), and mass event incident (MEI)
2. Discuss how an MCI creates a population-based context of care
3. Apply ATLS principles in disaster management
4. Describe principles of triage in the setting of an MCI and apply priorities of casualty care
5. Describe and demonstrate principles of allocation of resources in the ER and the OR during MCIs
6. Describe approaches to clinician safety in disaster management
7. Describe the structure and principles of Incident Command
8. Identify challenges for mass casualty care in austere or resource-constrained environments

17

Triage and Disaster Management

CHAPTER STATEMENT

The care of the individual injured patient must be expanded in a mass casualty incident or disaster situation. Effective application of ATLS® and triage principles are essential. In addition, trauma clinicians need to be familiar with disaster management principles, the Incident Command System, and unusual threats to safety. Finally, they should be prepared to function in austere conditions.

INTRODUCTION

Mass casualty and disaster management are very broad topics that require years of training and experience to master. This chapter will introduce you to the principles of triage, prioritization of care, and allocation of resources as they relate to mass casualty situations. **Mass casualty incidents require a change in concept from individual patient care to population-based care,** and we will show how ATLS® principles apply to disaster management as compared to treatment of individual patients.

The phases of disaster management will be summarized here but are described in detail in the Disaster Management and Emergency Preparedness (DMEP®) course, which is now available online. We will discuss the Incident Command System (ICS), a very common and important standardized approach to disaster management that is often not taught in medical education or surgical practice. Special attention also needs to be given to clinician safety, not just from the usual suspects such as needlesticks and blood-borne pathogens but also from chemical, biological, and radiological threats, and even from direct physical attack. Finally, we will discuss the challenges of mass casualty care in austere environments, whether in a low-income country or in a community that has just suffered catastrophic damage.

First, let's define a few terms. A mass casualty event (MCE) is a situation that generates multiple injured patients who stretch, but do not overwhelm, patient care resources. Resources may already be present or rapidly mobilized so that each injured patient receives individual care that follows the full ATLS paradigm. The number of simultaneous injured patients that constitutes an MCE varies by healthcare facility and community; there is more tolerance of multiple injured patients in urban settings.

A mass casualty incident (MCI) generates a large number of casualties with needs that exceed available healthcare resources and management systems for individual patient care. The mass casualty threshold varies between healthcare facilities and systems.

A mass event incident (MEI) is a situation that disrupts the capabilities of the normal healthcare system while also generating a large of number of casualties. If a healthcare facility is partially or completely destroyed, both the existing patients and new casualties must be relocated. These patients become an additional group in the overall casualty population. An MEI may result in no healthcare resources being available for the initial or extended response. Thus, an MEI is a catastrophic MCI. The transition points across this continuum will vary based on the situation, number and type of casualties, and available resources.

The fundamental challenge in an MCI is that casualty need exceeds resources that we normally use for individualized care. **When resources are scarce, a decision made for one of the injured impacts what can be done for every other injured person. The focus therefore must shift from "greatest good for the individual injured patient" to "greatest good for the casualty population."** Moving from an individual patient mindset to a mass casualty mindset may seem easy to apply in theory, but it is quite difficult in practice.

So how does one apply the concept of "the greatest good for the casualty population" in mass casualty situations? Mass casualty response is shaped by three dynamic variables: situation, casualties, and resources. The goals in mass casualty management are quick identification of and initiation of care for critically injured, salvageable casualties, and keeping clinicians, staff, and hospitals safe.

Most casualties are not critically injured and are tolerant of deferred care (e.g., soft-tissue wounds, distal extremity fractures). This type of casualty often self-transports to the closest hospital (geographic effect), and clinicians must be cautious when presented with these patients early during the MCI; they could start providing care to these noncritical casualties and use up precious resources before the arrival of critical casualties. The usual acceptance of high overtriage rates during routine, individual-focused trauma care can lead to higher mortality of critical casualties during an MCI, because it causes delay in identifying and caring for them.

The initial goal of triage in an MCI is to identify critically injured casualties and prioritize their movement across healthcare settings (e.g., evacuation from the scene to the hospital, movement from hospital arrival to the emergency department). In prehospital casualty assessments at and away from the scene, triage ascertains who is alive and who is dead, and then who among the living needs immediate care and who does not. At hospitals, triage officers exist at the point of casualty arrival and at each care setting (trauma rooms, OR, ICU, ward).

The trauma triage officer is responsible for prioritizing which critical casualties get the scarce resources (surgical personnel, OR, radiological studies, ICU beds, etc.) right away and who must wait. **Triage officers do not necessarily need to be physicians,** but they do need to be experienced in rapid shock assessment and acute decision-making. They do not provide more than very quick lifesaving interventions but instead focus on assigning teams to care for these critical casualties.

ATLS principles can provide another lens through which to look at mass casualty management. The primary survey provides the framework for initial casualty assessment and intervention at the scene and beyond (■ **Figure 17-1**). Critically injured, salvageable casualties may present with primary survey findings that require rapid interventions for controlling exsanguinating hemorrhage, establishing an airway, and decompressing a tension pneumothorax.

Secondary survey, imaging, and definitive care are deferred until all critically injured, salvageable casualties are stabilized. Utilize damage control interventions in the emergency department and OR to maximize the opportunity to save more lives. As the situation becomes more certain and resources are mobilized, critical casualty care advances to secondary survey, definitive care, and potential transfer. Reassessment and management of noncritically injured casualties also become possible (**■ Figure 17-2**).

Besides immediate critical casualties, there are other categories that will be identified during the course of an MCI (**■ Figure 17-3**).

PREHOSPITAL EVALUATION

In the initial prehospital and inhospital evaluations, the only triage decisions to be made are the determination of who is alive, who is dead, who among the living needs immediate care, and who does not. Once in the hospital, further discrimination into the other categories and reassessment of initial triage decisions can occur. The "expectant" category (alive but expected to die even with treatment) is most representative of the essential difference between mass casualty management and routine emergency care. The denial of care to individuals so severely injured that they are unlikely to survive means that the limited time and resources available can be diverted to many others who are less severely injured, thus avoiding many more preventable deaths. **This fact is the essence of the principle of doing the greatest good for the greatest number**.

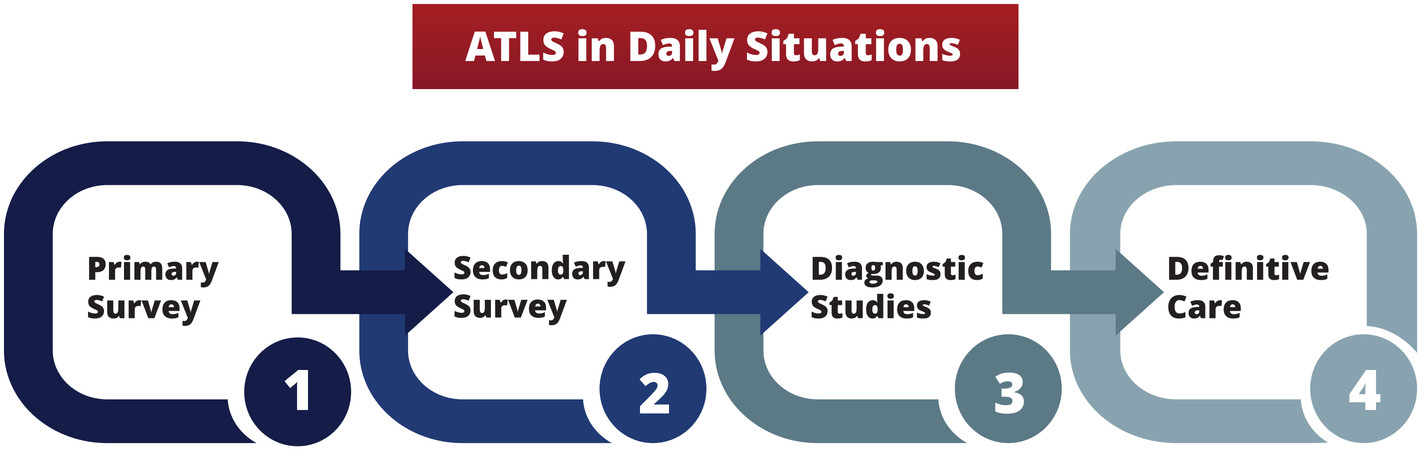
The accuracy of triage is a major determinant of casualty survival and the success of the medical management of MCIs. The major errors of triage are *undertriage*, the assignment of critically injured casualties to delayed care, and *overtriage*, the assignment of noncritical casualties to immediate care. In certain mass casualty settings, both errors have been directly correlated with the critical mortality rate, and both errors must be minimized to optimize the outcome.

A triage officer must understand the nature of injuries to be anticipated and be educated in the unique principles of mass casualty handling; this individual also must have absolute authority to make these critical decisions. Situational awareness is another essential attribute of an effective triage officer. This characteristic consists of a working knowledge of the constantly changing status of casualty influx from the scene, the nature of injuries encountered, the casualty flow, and available resources—space, personnel, material—within the hospital, all of which are essential to making the appropriate decisions.

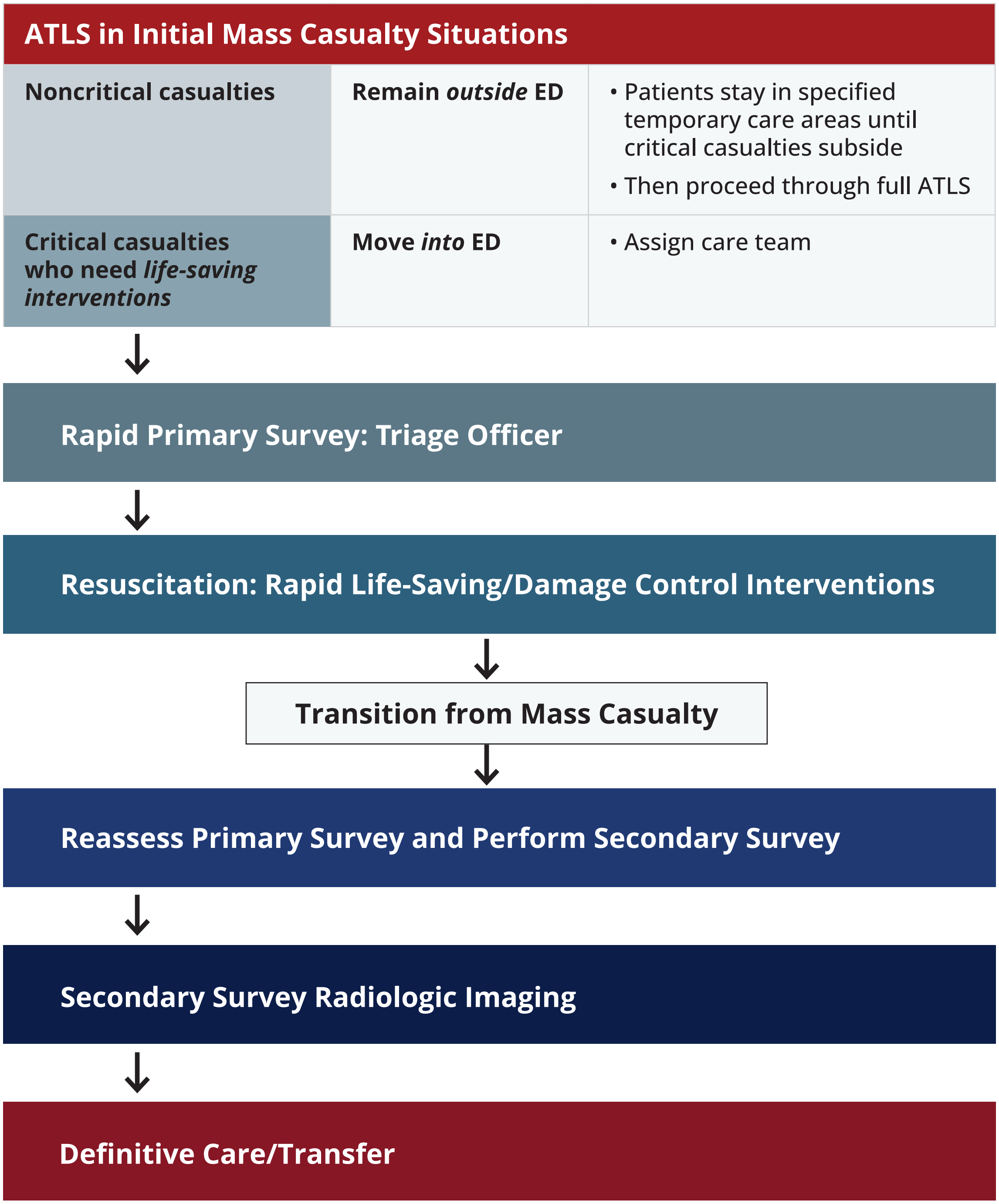
Triage errors should be expected in the chaos of these incidents, even under the best circumstances and with extensively trained triage officers. This fact emphasizes the need to create an error-tolerant system that mitigates the adverse effects of triage errors. Examples of this type of system include continual monitoring and reassessment of casualties assigned to nonurgent categories for deterioration (to minimize undertriage) and establishing levels of secondary and tertiary triage to continually screen out individuals who do not need urgent care (to minimize overtriage). The postincident analysis and critique of a disaster, which is an essential element of all disaster responses, should include a determination of triage accuracy and its impact on casualty outcome.

In the context of the ATLS Course, triage is the most important concept to understand and is familiar to most trauma and emergency department practitioners. However, disaster management requires familiarity with many other concepts, including the *phases of disaster management, incident command, and safety,* which are not encountered in daily trauma care. We provide only a summary of these concepts here, but additional information can be obtained from the in-person or online DMEP course.

■ Figure 17-1: ATLS in Individual Trauma Patient Care. In typical daily trauma situations, the initial assessment and management of the patient follows a standardized longitudinal progression.



■ **Figure 17-2: ATLS in Mass Casualty Situations (MCIs).** In MCIs, the primary survey with immediate resuscitation provide an opportunity to save more lives while deferring the secondary survey, diagnostic studies and definitive care until salvageable critical casualties have been stabilized.



ATLS in Initial Mass Casualty Situations		
Noncritical casualties	**Remain *outside* ED**	• Patients stay in specified temporary care areas until critical casualties subside • Then proceed through full ATLS
Critical casualties who need *life-saving interventions*	**Move *into* ED**	• Assign care team

Rapid Primary Survey: Triage Officer
Resuscitation: Rapid Life-Saving/Damage Control Interventions
Transition from Mass Casualty
Reassess Primary Survey and Perform Secondary Survey
Secondary Survey Radiologic Imaging
Definitive Care/Transfer

■ **Figure 17-3: Mass Casualty Triage Categories** reflect the rapid categorization of casualties at a casualty collection site or at a medical facility.

Mass Casualty Triage Categories

Triage Category	Clinical Presentation	Action
Immediate (Red)	Unconscious, or no pulse, or respiratory distress, or life-threatening hemorrhage, AND likely to survive given current resources.	Initiate life-saving interventions. In hospital, this may include damage control surgery.
Delayed (Yellow)	Conscious, have a pulse, no respiratory distress, no life-threatening hemorrhage, AND have significant injuries.	Monitor and support until definitive care or transfer can be arranged. Deterioration or new information may necessitate change to immediate.
Minimal (Green)	Conscious, have a pulse, no respiratory distress, no life-threatening hemorrhage, AND have minor injuries.	Monitor until secondary survey completed. Provide minor treatment and discharge. Deterioration or new information may necessitate change to delayed or immediate.
Expectant (Various)	Unconscious, or no pulse, or respiratory distress, or life-threatening hemorrhage, BUT NOT likely to survive given current resources.	Initiate comfort care. Some may become immediate if more resources become available.
Dead (Black)	No signs of life.	At scene leave in place. At hospital, transfer to morgue or other secluded location.

PHASES OF DISASTER MANAGEMENT

The phases of disaster management include a Ready phase, a Response phase, and a Recovery phase:

READY PHASE

This phase includes *planning* and *mitigation*. Appropriate responses to disasters are so rapid and complex that they cannot possibly happen without advanced thought and planning by all involved parties. As such, every hospital and community should have preestablished plans for disasters. Planning should anticipate the requirement for self-sufficiency at the local level for at least 5 days before the arrival of outside help. These plans must be rehearsed regularly with hospital drills and community exercises to reveal any weaknesses that should be addressed.

At the same time, disaster plans must have a built-in flexibility to allow adaptation to the unpredictable variables unique to each disaster. All personnel expected to respond to a disaster should prepare themselves by acquiring core knowledge of all elements of disaster management, as well as a good understanding of the unique aspects of casualty medical management, including those required for unusual situations involving chemical and radioactive materials or explosives. *Mitigation* is the implementation of measures aimed at reducing or eliminating the chance of a disaster. From a medical perspective, this may include injury prevention efforts.

RESPONSE PHASE

The initial focus of attention and efforts in any disaster is the disaster scene, where the nature and extent of the incident must be assessed, further damage minimized, and appropriate plans formulated to deal with the damage. The more extensive the destruction at the scene, the more important it is for an advance team of responders to carry out a needs assessment to determine what assets are required for a successful response. Any hazardous material dissemination must be identified at this point to define the need for decontamination of casualties and protection of first responders.

Security measures must be established rapidly to restrict access to the scene to only trained individuals, as lives could be unnecessarily lost among well-intentioned but untrained people encountering falling debris, ongoing fires, smoke and dust inhalation, and chemical or radiological exposure. **Security measures can also prevent deliberate "second hit" events** designed to kill first responders a short time after the initial incident. Protection of medical assets must be a priority of the prehospital response. Medical management of a mass casualty incident begins at the disaster scene with search and rescue. The initial evaluation should involve only a rapid triage decision as to who needs immediate care for life-threatening problems and who does not, with the former being transferred to hospitals first.

Every hospital in a disaster incident must prepare for a large influx of casualties by rapidly clearing its emergency department, OR, and ICU beds to the fullest extent possible and by mobilizing personnel and equipment resources while initiating the hospital's disaster plan. Space, personnel, and equipment must also be allocated to manage the routine patients who will continue to seek hospital services even during disasters. A security mechanism (hospital lockdown) should be instituted to prevent chaotic inundation of the hospital by casualties, worried families, the media, and curious onlookers from the outside. Similarly, an internal procedure must be initiated to prevent care spaces from being inundated by well-intentioned medical personnel who may create more chaos and harm due to overcrowding. Triage officers at each point of care will need to allocate available resources, assign care teams, and manage patient flow to the next point of care.

RECOVERY PHASE

Within 24 hours of an MCI, and after definitive treatment has been initiated for all patients, a debriefing of all involved personnel should be facilitated, including evaluation of procedures that worked well and those that did not, bottlenecks, and resources that became depleted. Communication issues should be raised and discussed. Over the next 2–3 months, key stakeholders should collate this data, determine critical mortality and triage accuracy, and assess clinical outcomes. These data should be the basis for improvement efforts in planning for the next disaster.

The hospital may need government or financial assistance to repair facilities, restart services, or even backfill personnel and equipment. There are numerous government grant and loan programs for businesses and individuals to tap, including hospitals and healthcare personnel.

While physical damage to infrastructure can be repaired and injuries can heal, psychological damage can be more difficult to assess and address. Reunification of families, support provided by friends and family, and psychological first aid given by laypeople to casualties are the beginning of psychological recovery after a disaster. It is important to remember that **healthcare professionals may benefit from trauma-informed care as much as patients and families**. The emotional impact of disasters on everyone cannot be overemphasized. Some affected individuals never recover. Others develop long-term mental illness or behavioral changes, which often require professional intervention.

INCIDENT COMMAND SYSTEM

The ICS is a standardized, all-risk incident management framework. ICS allows its users to adopt an integrated organizational structure to match the complexities and demands of single or multiple incidents without being hindered by jurisdictional boundaries. In a disaster response, the traditional management structures should not be used. The four Cs of the ICS are Communication, Coordination, Cooperation, and Collaboration. They are four simple words, but they can have far-reaching implications.

ICS is applied to ensure coordination among all organizations potentially responding to the disaster. ICS is a modular and adaptable system for all incidents and facilities and is the accepted standard for all disaster response. The Hospital Incident Command System (HICS) is an adaptation of the ICS for hospital use. It allows for effective coordination of hospital response activities with prehospital, public health, public safety, and other organizations. The trauma system is an important component of the ICS. Various organizations and countries have modified the structure of the ICS to meet their specific organizational needs.

Functional requirements, not titles, determine the ICS hierarchy. The ICS is organized into five major management activities: Incident Command, Operations, Planning, Logistics, and Finance/Administration. Key activities of these categories are listed in ■ **Figure 17-4**.

■ **Figure 17-4: Incident Command System.** A key incident management structure that ensures optimal coordination of all organizations responding to a mass casualty situation.

Incident command structure and components	
Incident Commander (IC)	• Sets objectives and priorities and maintains overall responsibility for the disaster. • The IC is assisted by the Liaison Officer, Public Information Officer, and Safety Officer.
Operations	• Conduct operations to carry out the Incident Action Plan (IAP). • Direct all disaster resources, including medical personnel.
Planning	• Develop Incident Action Plan(s). • Collect and evaluate information. • Maintain resource status.
Logistics	• Provide resources and support to meet incident needs, including responder needs.
Finance/Administration	• Monitor costs, execute contracts, provide legal advice. • Maintain records of personnel.

The structure of the ICS is the same regardless of the disaster; the difference is in the particular expertise of key personnel. An important part of hospital disaster planning is to identify the incident commander and other key positions before a disaster occurs. The positions should be staffed 24 hours a day, 7 days a week during a disaster. Each person in the command structure should supervise only 3–7 persons. This approach is significantly different from conventional hospital management. All medical clinicians must be aware of and adhere to the ICS structure to ensure that they integrate successfully into the disaster response.

Clinician safety is paramount during an MCI. In the field, situational awareness is critical to avoid becoming a casualty oneself. There are many hazards to watch for, including vehicular accidents, trips and falls, collapsed or damaged structures, cuts and burns, infectious disease, smoke, CBRN (chemical, biological, radiological, nuclear) exposure, unsecured weapons, explosives, bad weather (lightning, swift water, heat and cold), exposed or damaged electrical and gas lines, and hostile activity.

Proper personal protective equipment (PPE) is required. This may be nonmedical, such as work gloves, rubber gloves, hard hats, boots, goggles, and head lamps, or medical, such as surgical gloves, masks (such as N95 or higher respiratory protection with chemical filtering), and impermeable coveralls. **If radiation is known or expected, responders should have personal dosimeters** to assess time permitted on scene and to provide confirmation of inconsequential exposure.

At the hospital, all casualties suspected of being contaminated with biologic toxins, hazardous chemicals, or radioactive particles should be decontaminated before entering the emergency department. Otherwise, the facility becomes contaminated and dangerous for patients, clinicians, visitors, and other casualties. Surface decontamination at a minimum requires removal of clothing and washing with soap and water. Lifesaving measures such as hemorrhage control, chest decompression, airway control, and administration of antidotes can be done at any stage of care, including before decontamination. However, clinicians must wear appropriate PPE. After decontamination, standard contact precautions are appropriate.

Finally, consideration should always be given to the possibility of a MEI. What if there is so much damage to healthcare infrastructure that medical care cannot be provided? Tornados have destroyed hospitals here in the US, earthquakes have destroyed hospitals from Haiti to China, and war—the ultimate human-caused disaster—has destroyed entire countries' healthcare systems. Such catastrophes may require evacuation of casualties out of the disaster zone or transport of entire field hospitals into the disaster zone. **Evacuation procedures should be part of every hospital's disaster plan.** More information about this topic can be found in the DMEP Course.

CHAPTER SUMMARY

This chapter introduces the ATLS learner to the principles of triage, prioritization of care, and allocation of resources as related to mass casualty situations. It also summarizes the phases of disaster management, the ICS, and safety concepts, both at the scene and at the hospital. Finally, it asks the learner to consider what should be done in a catastrophic situation with no available resources. Mastering all these concepts requires years of training and experience, but this chapter and the accompanying triage scenarios provide at least a starting point. The next steps suggested include DMEP and other courses, which can be found via the links provided below.

American College of Surgeons Disaster Management and Emergency Preparedness (DMEP) Course: www.facs.org/quality-programs/trauma/education/dmep.

KEY LEARNING POINTS

- **Mass casualty incidents require a change in concept from individual patient care to population-based care**
- **ATLS principles are the same, but are applied differently during MCIs**
- **The phases of disaster management include a Ready phase, a Response phase, and a Recovery phase**
- **The ICS is a standardized, all-risk incident management framework which allows its users to respond effectively to single or multiple incidents without being hindered by jurisdictional boundaries**
- **Maintaining clinician safety is important**
- **Maximize available resources to save as many as possible**
- **Plan for austere conditions and the possibility of a Mass Event Incident (MEI)**

REFERENCES

1. Committee on Trauma of the American College of Surgeons. *Disaster Management and Emergency Preparedness Course Student Manual. 2nd Edition*. Chicago, IL; 2018.
2. FEMA National Disaster and Emergency Management University. IS-100.C: Introduction to the Incident Command System, ICS 100. https://training.fema.gov/is/courseoverview.aspx?code=IS-100.c&lang=en. Accessed September 28, 2024.

18

Injury Prevention

OBJECTIVES

After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Describe how the conceptual framework of the Three Es can be used to design locally relevant injury prevention initiatives
2. List specific risk factors and prevention strategies by mechanism of injury
3. Discuss how social determinants/drivers of health and other factors may lead to a disproportionate burden of injury on certain populations
4. Describe how the use of tailored screening tools can assist in identifying child abuse, intimate partner violence, abuse of older adults, and mental health concerns and can then be used to arrange appropriate referrals

18

Injury Prevention

CHAPTER STATEMENT

Injuries are **not** "accidents" but predictable, and therefore preventable, events. Strong injury prevention work has resulted in significantly reduced trauma mortality, but there is still much more work to do in the areas of road traffic injuries, elderly fall injuries, childhood burns, and firearm violence (among others). Injury prevention priorities differ by region and context.

Trauma care clinicians are key stakeholders in injury prevention, as they often have the most current and locally relevant information on what should be prioritized. During initial resuscitation, trauma care clinicians also have the unique opportunity to gather information from prehospital personnel that may be pertinent in devising or evaluating injury prevention strategies, both to prevent reinjury in the patient immediately under their care and for preventing future injury among members of the local community. Simple frameworks, such as the "Three Es" (**environment/engineering**, **education**, and **enforcement**), can be readily applied to common injuries to help design locally relevant injury prevention interventions.

This chapter will provide learners with concepts of how to approach injury prevention and obtain ideas using the Three Es. It is understood that different measures, laws, policies, and so on may be required in various regions of the world depending on resources and philosophy, but this chapter was written as a foundation for learners to create appropriate evidence-informed interventions in their respective domains.

INTRODUCTION/BACKGROUND

While advances in trauma care have enhanced survival, such improvements alone cannot eliminate the impact of trauma. Injury prevention efforts are a critical necessity to reduce the morbidity and mortality of trauma unaddressed through trauma care. **Although unintentional injuries are sometimes called "accidents," they are often predictable (and therefore preventable) events.** An example of this is looking at the geographic distribution of road traffic injuries across a city map. These events will not be evenly distributed across the city; rather, they will cluster in certain areas and along certain routes, impacting some areas more than others. These "hot spots" provide an opportunity for us to look for the root causes of these injuries. Some examples include poor traffic light timing; signage for a pedestrian crossing that is not easily visible; and proximity to bars or other liquor outlets that influence road user intoxication.

Careful consideration of the *social determinants of health (SDOH)*, also referred to as the *social drivers of health (SDOH)*, is essential; these are often at the root of both injury risk factors and protective factors. For example, do the injury events occur in areas where people are more likely to be unhoused or economically disadvantaged?

Identifying these root causes has been the foundation of modern injury prevention. By discovering risk factors and protective factors associated with injuries, effective interventions have been created that have significantly reduced the burden of trauma in the US. These interventions are often taken for granted; society benefits from improvements like airbags and crosswalks without having to think much about them; but the reduction in injury mortality in the US (and in many other countries) has been due to consistent societal efforts from multiple stakeholders.

As the people standing on the front lines and managing the consequences of injury, trauma care clinicians are key to successful injury prevention measures. Although it is impossible to prevent an injury that has already happened, clinicians caring for trauma patients have a unique opportunity to identify trends in their areas. Certain injury mechanisms are associated with specific risk factors that should alert trauma clinicians to the potential need to employ injury prevention principles and strategies.

As they are exposed to the immediate impacts of trauma in their communities, clinicians can readily incorporate injury prevention frameworks such as the Three Es (discussed below) to specific injury mechanisms (such as ground-level falls in elderly patients, firearm-related violence, and pedestrian road traffic injury) or contexts they commonly see (including when risk factors such as intoxication or mental illness are involved). These trends not only are an opportunity but also confer a responsibility to prevent reinjury in the patient immediately under a clinician's care, as well as future injury in other patients with similar risk factors.

Timely identification of injury mechanism patterns and consistently identified risk factors among patients can alert the trauma care clinician to key areas of potential intervention within the local community. Additionally, there are multiple screening tools available in the literature for special classifications such as mental health, intimate partner violence (IPV), and child and elder abuse and neglect; there will be a brief referral to an evidence-informed tool for each topic mentioned.

CONCEPTS/APPROACHES TO INJURY PREVENTION:

There are several frameworks and guiding principles used as structures to develop strong injury prevention practices. No approach is necessarily superior to another; rather, they simply represent different ways of looking at the same issue. This chapter will focus primarily on the Three Es approach, though other approaches will also be discussed briefly. For more information, please see the references.

The Three Es:

- **Environment/Engineering**
- **Education**
- **Enforcement**

These were originally thought of as separate approaches and could be arranged on a spectrum of most effective—**engineering/ environmental changes**—to least effective—**education**—while also following a spectrum from passive interventions, which require minimal individual decision-making, to active interventions, which require more complex individual behavior change to be effective (see below). More recently, the Three Es are used together to create multipronged interventions, not only because many interventions inherently require more than one element but also because a multipronged approach tends to be more effective. An example of this is seat-belt use, which requires elements of engineering changes, education, and enforcement. Although this intervention took effort and time to be successfully implemented in the US, it ultimately was extremely effective in reducing the morbidity and mortality of road traffic injury.

The Three Es are a practical framework that clinicians can quickly use to assess the context and risk factors associated with a patient's injury, allowing early identification of potential injury prevention targets. It is particularly important to remember to communicate contextual information regarding a patient's injury during handoff or transfer to definitive care—the Three Es are an effective tool to guide this communication. ■ **Figure 18-1** demonstrates how a clinician might conceptualize the Three Es to design and implement motor vehicle crash prevention initiatives.

Some have advocated for a fourth "E" in this framework, "Equity," to account for the fact that injury is disproportionately experienced by some people and to ensure that interventions are applied fairly.

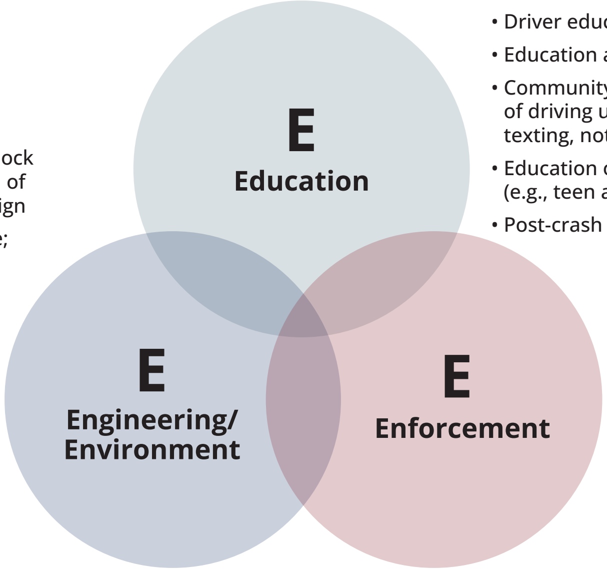
PASSIVE VERSUS ACTIVE INTERVENTIONS

Passive interventions do not require a person to make the decision to use the intervention—it just happens for them. Examples of this are hot water heater regulators in the US (preventing childhood burn injuries) or airbags (preventing road traffic injury). **Active** interventions require the user to make the decision to use the intervention each time. An example of this is the seat belt, which requires the user to choose to buckle up each time they ride in a car. Passive interventions tend to be more effective but often require a significant up-front investment of political will or policy development (like water heater temperature regulation). Once implemented, however, they are very efficacious because they do not require each individual to make the safer choice every time they have a decision to make.

HADDON'S MATRIX

Haddon's Matrix was developed by William Haddon, who is considered the "father" of modern injury prevention; it was a key conceptual advancement in the history of injury prevention. Haddon's Matrix deconstructs the injury event into "human," "agent" (e.g., vehicle), and "environmental" factors along temporal opportunities for intervention ("pre-event," "event," and "postevent"); each intersection provides potential opportunities for intervention (e.g., airbag deployment would be a prevention measure that occurs during the event and is inherent to the "agent"—in this case, the vehicle). The matrix is still used as a brainstorming tool to develop effective interventions. In the original 1968 publication, a "template" was shown describing how one might use the matrix in brainstorming interventions for highway-related injuries (■ **Figure 18-2**).

■ **Figure 18-1: The Three Es Concept.** The Three Es concept offers a multi-faceted approach to considering causes of and potential strategies to prevent injury.



Engineering/Environment
- Vehicle design/handling; anti-lock brakes; presence and position of airbags; up-to-date safety design
- Road design and maintenance; adequate signage; mitigation of glare (night or bright sun)
- Analysis of unanticipated consequences (e.g., fire from gasoline tank or electric vehicle battery)
- Presence of organized emergency response and appropriate care facilities

Education
- Driver education courses
- Education about vehicle maintenance
- Community education: consequences of driving under influence, speeding, texting, not using restraints
- Education of special populations (e.g., teen and older drivers)
- Post-crash counseling and education

Enforcement
- Advocacy for legislation regarding substance use, speeding, restraint use, and texting while driving; resource support for infrastructure maintenance and speed limits
- Analysis of effective enforcement of speed limits, vehicle functioning, restraint use: analysis of substance use and/or driving distractions
- Community/Societal advocacy for pre-hospital, acute trauma, and rehabilitation care; enforcement of screening for SDOH

■ **Figure 18-2: Haddon's Matrix.** The original template was constructed to apply public health principles to addressing traffic safety. It is now used to assist in developing ideas for injury prevention across a broad range of mechanisms.

Component / Phase	Driver	Passengers	Pedestrians	Bicyclists	Motor-cyclists	Vehicles	Highways	Police
Precrash								
Crash								
Postcrash								
RESULTS	**Driver Injury & Death**	**Passenger Injury & Death**				**Property Damage**		

TIME

CENTERS FOR DISEASE CONTROL AND PREVENTION (CDC) PRINCIPLES: PRIMARY, SECONDARY, AND TERTIARY PREVENTION

The public health approach principles to prevention are based on interrupting disease and injury, prolonging life, and promoting health. These principles will be described below.

- Primary Prevention: Focuses on the general population by halting disease, risky behaviors, or violence from happening (e.g., raising awareness of the detrimental effects of committing relationship or sexual violence, setting up driving under the influence checkpoints, reducing access to weapons, use of noncombustible construction material)
- Secondary Prevention: Addresses screening at-risk individuals to identify a disease in its early stage or intervening after a violent act has occurred to diminish its recurrence (e.g., educating victims of relationship and sexual violence of red flags associated with wrongdoers, community violence intervention, safety belt use, less-lethal bullets, smoke detectors)
- Tertiary Prevention: Focuses on the long-term consequences of disease or violence by providing support for affected persons (e.g., family justice centers or recovery homes, rehabilitation centers, access to emergency medical services or equivalent of 911 system, access to quality healthcare)

RELEVANCE TO INITIAL PATIENT MANAGEMENT

Every level of care across the spectrum (prehospital, initial center, referral center) has a role to play in ensuring that the causes of injury are understood so that they may be prevented. **While rapid clinical evaluation and stabilization must be prioritized, often the initial presentation of the injured patient provides context to the injury event that is relevant to injury prevention.** Details such as the incident location and surrounding environmental characteristics may provide valuable information related to injury risk and protective factors. Examples of this include the following:

- Road traffic injuries: Did the event happen at the corner or middle of a street? Was there a traffic violation? Was a helmet worn? Was the victim under the influence of alcohol or other substances? Is there a mental health history? Is the patient housed?
- Violence: Was there substance use involved? Was a firearm used in the incident? Were there social determinants of health at play, such as poor housing?
- Falls in older adults: Where did the event occur: at home or in a care facility? Were there risk factors like rugs or stairs with poor footing? Is elder abuse suspected?

It is important to treat each patient with the same level of dignity that follows trauma-informed care principles (see *Chapter 19, Trauma-Informed Care and Social Determinants of Health*), including recognizing how prior trauma may influence current behaviors. If a patient is transferred to another facility or higher level of care, it is important to transmit all the relevant information, including the injury context. **If a patient ultimately arrives at a Level I trauma center for definitive care, there should be injury prevention data collection programs in place that will greatly benefit from information on the patient's injury context, risk factors, and protective factors.** Once lost, this information is often irretrievable or requires significant effort to recapture, so the facility providing initial care plays a key role.

The Three Es framework is a simple construct that can be readily used to aid in this communication. For example, a trauma care clinician who takes care of an injured older adult person after a fall may have information regarding the injury context that could be critical in preventing a future fall by that same patient. Framing these factors as **engineering** (lack of handrails) or **education** (patient or family education regarding medication review or vision checks) may be key in both protecting the individual patient against another injury and helping plan effective community-level injury prevention programs.

PRACTICE ENVIRONMENT CONSIDERATIONS

The level of injury prevention intervention should be tailored to the resources and injury epidemiology at each facility. Even smaller facilities can play an important role in injury prevention. For example, if a number of pedestrian injuries are noted to present to a smaller facility, careful understanding of the injury context may reveal that they are happening in the same location or intersection. This intersection may be amenable to a simple, locally controlled injury prevention measure. Road traffic injuries are particularly amenable to environmental injury prevention interventions such as scramble crosswalks, improved traffic light timing to protect vulnerable road users, or interventions to separate traffic mix. Vision Zero is an example of a locally driven movement that has gained international scope (■ **Box 18-1**).

Injury prevention principles are applicable in diverse settings, even in austere environments. Low-income countries have approximately 1% of the world's road vehicles but suffer 13% of the deaths due to road traffic injuries; road traffic injury is the leading cause of death in people ages 1–29 globally. Many low- and middle-income countries have successfully implemented injury prevention strategies despite limited resources. For example, Bogota, Colombia, reduced road traffic mortality from 1996 to 2006 by 50% through a multipronged strategy including improvement of infrastructure (**engineering/environment**), institution and **enforcement** of regulations such as seat-belt use and drunk driving penalties, and strong leadership that provided effective communication to the population (**education**). Principles exemplified by the Bogota experience—effective regulation, enforcement, road condition modifications (**environment/engineering**), and population-level **education**—are applicable and implementable in a variety of contexts. Examples from low- and middle-income countries underscore the power of injury prevention in any context to significantly reduce injury morbidity and mortality. **Trauma clinicians in any setting can make meaningful contributions to these efforts. Clinicians are advised to review, identify, and evaluate risk and protective factors to initiate optimal injury prevention strategies according to their institution's capacity.**

■ **Box 18-1: Vision Zero.**

Vision Zero

- Vision Zero is an example of a movement that started locally in Sweden over 20 years ago, and now has international momentum. Most major cities have Vision Zero programs toward which trauma centers can contribute meaningful data to inform prioritizing interventions.
- In San Francisco, hospitals contributed nonfatal injury data, which are historically under-captured by police data sources, to provide accurate information for intervention prioritization, monitoring, and evaluation (REF).
- An example of misaligned priorities occurred in one major city in an low- and middle-income country, where local injury-prevention policy focused on airbag legislation, but local clinicians had observed most severe injuries occurring in pedestrians and people falling off trains they had "hopped" on (riding on a train's roof or side), which would not be impacted by the proposed intervention. Globally, local trauma care clinicians have important perspectives that are essential to relevant and effective injury prevention.

SPECIFIC INJURY RISK FACTORS/ PREVENTION STRATEGIES BY MECHANISM

■ **Table 18-1** depicts certain risk factors that can propagate injury mechanisms, and possible prevention strategies. As part of the initial assessment of a trauma patient, clinicians should also consider which of these risk factors may have contributed to the traumatic event, as well as some of the accompanying potential prevention strategies.

SPECIAL POPULATIONS CONSIDERATIONS

Trauma is particularly impactful on certain populations. These populations may also be disproportionately impacted by social determinants of health such as poverty, structural racism, poor access to education, and poor health outcomes in other realms. Social determinants/drivers of health not only put individuals at risk for injury but also increase the likelihood of poor outcomes after injury. In planning injury-prevention interventions, trauma clinicians should consider which populations are most at risk for injury and poor outcomes after injury among the community they serve.

In some settings in the US, falls in older adults, pediatric injuries, vehicle-pedestrian conflicts, or motorcycle collisions are overrepresented. In other settings, young Black men appear disproportionately affected by violence; interventions that carefully consider what might be most effective in a given population may prevent repeat injury and improve quality of life. Successful hospital-based intervention programs prioritize strong, long-term, peer-mentored case management and close partnerships with community-based organizations, underscoring the key role first-line trauma care hospitals have in injury prevention.

■ **Table 18-1: Injury Mechanisms, Risk Factors, and Prevention Strategies.** Understanding the risk factors that make injury more likely with certain mechanisms makes it easier to apply prevention approaches and concepts like the 3Es.

MECHANISM	RISK FACTORS	PREVENTION STRATEGIES
Elderly Falls	• Frailty • Environmental factors	• Syncope work-up • Falls assessment • Home safety check • Medication reconciliation
Interpersonal Violence	• Poverty • Other social determinants of health	• Hospital-based violence Intervention programs • Screening/Education • Housing/Relocation • Employment
Self-Injury	• History of depression • Ready access to firearms • Alcohol or intoxicants	• Primary care provider (PCP) screening • Public awareness • Advocacy for increased mental health access
Falls from Heights (Construction)	• Lax safety measures • Alcohol or intoxicants	• Safety legislation • Safety checklist, e.g., equipment inspection, double guard rails, harnesses
Motorcycle Injury	• Lack of helmet laws • Alcohol or intoxicants	• Safety legislation • Protective gear
Automobile-Pedestrian Conflict	• Alcohol or intoxicants • Poor street design • Age	• Public awareness • Night-time bright clothing • After-dark reflectors
Unintentional Firearm Injury	• Firearm access	• Firearm safety education • Gun locks • Education
Intimate Partner Violence (IPV)	• Prior exposure to intimate partner violence • Socioeconomic factors • Unhealthy coping mechanisms and relationship interactions	• Education • Screening at all levels of care • Safety legislation

Hospital-based violence intervention programs are an example of how hospital-based interventions can have a direct impact on reducing injury in the surrounding community and have demonstrated important reduction in reinjury, improved social and health outcomes, and cost-effectiveness. Understanding important social and structural aspects of injury prevention can also improve the direct delivery of clinical trauma care through aforementioned practices such as trauma-informed care (see *Chapter 19, Trauma-Informed Care and Social Determinants of Health*).

INJURY PREVENTION SCREENING TOOLS

Trauma clinicians are key members of the injury prevention community, with ready access to those most at risk. Individual clinicians can consider the populations and injury mechanisms most commonly encountered at their institution and implement relevant screening tools. At the institutional level, routine screening may be integrated into standard trauma care for conditions frequently affecting the trauma population seen at that facility.

When initiating a screening process, **it is important to ensure that resources are available to make the appropriate referrals if risk factors or evidence of harm are identified.** If these resources are not available at the facility performing the initial screening, the results should be communicated to the definitive care facility. If the initial treating facility regularly sends patients to the definitive care facility, a robust, collaborative screening/referral process should be established between the institutions.

Screening tools exist to address a variety of disease processes and health concerns. Some that are related to injury include but are not limited to the following.

MENTAL HEALTH

One of the primary contributors to postinjury quality of life is post-traumatic psychological distress. Although post-traumatic sequelae are not limited to these two disorders, depression in trauma survivors is reported to vary from 30%–40%, while post-traumatic stress disorder rates are 20%–30%, hence the new requirement in the *Resources for Optimal Care of the Injured Patient (2022 Standards)* for screening at-risk trauma patients. See *Chapter 19, Trauma Informed Care and Social Determinants of Health,* for further detail.

INTIMATE PARTNER VIOLENCE

IPV is defined as physical or sexual violence, stalking, reproductive coercion, or psychological aggression by a current or former intimate partner of the victim. It is critical to realize that anyone can be a victim, regardless of global geographic location, income, education, race, ethnicity, age, or professional role. IPV is not specific to relationships with sexual intimacy. It can occur in both men and women, in heterosexual and same-sex relationships. It is estimated that 1 in 4 women and nearly 1 in 10 men will experience IPV during their lifetime, far exceeding other common diseases such as breast cancer and heart disease (■ **Figure 18-3**).

CHILD ABUSE AND NEGLECT

Like IPV, child maltreatment is a global phenomenon. In the US, neglect is the leading cause of mortality due to child abuse or maltreatment. It has long-term consequences for children and confers a substantial economic burden. Strategies to intervene and prevent ongoing maltreatment rely on early identification of children at risk (■ **Figure 18-4**).

OLDER ADULT (ELDER) ABUSE AND NEGLECT

Data show that abuse affects 1 in 6 older adults worldwide, amounting to approximately 141 million people. Demographic projections indicate that the proportions of elderly will continue to grow such that 25% of the world's population will be aged 60 or above by 2050. There are six different forms of elder abuse: physical, psychological, sexual, financial, neglect, and violation of personal rights (■ **Figure 18-5**).

■ **Figure 18-3: HARK Questions.** All patients should be screened for IPV regardless of gender, global geographic location, income, education, race, ethnicity, age, or professional role. IPV is not specific to relationships with sexual intimacy. It can occur in heterosexual and same-sex relationships.

HARK QUESTIONS	
H	**HUMILIATION** Within the last year, have you been humiliated or emotionally abused in othe ways by your partner or your ex-partner?
A	**AFRAID** Within the last year, have you been afraid of your partner or ex-partner?
R	**RAPE** Within the last year, have you been raped or forced to have any kind of sexual activity by your partner or ex-partner?
K	**KICK** Within the last year, have you been kicked, hit, slapped, or otherwise physically hurt by your partner or ex-partner?

One point is given for every "yes" answer.
Anyone that scores ≥1 is positive on the HARK screening tool.

■ **Figure 18-4: Child Abuse Screening Tool.** Many localities require reporting of suspected child abuse and neglect. A standardized tool to assess for abuse/neglect allows for more accurate screening and lessens the chance of missed injury. Note that it is important to use such a tool as part of a protocol that includes appropriate resources for referral.

CHILD ABUSE SCREENING TOOL

Disclaimer: "A positive child abuse screen will initiate an electronic physician notification and does not necessarily mean that sufficient suspicion exists to warrant mandated child abuse reporting."

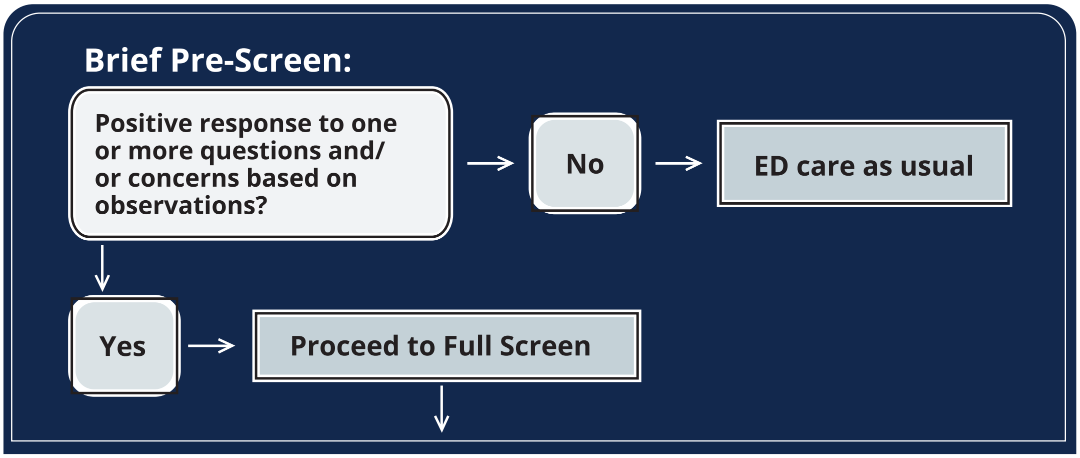
Are there potential safety concerns for the child related to any of the following?

1. Was there a possible delay in seeking medical attention given the severity of illness or injury?	○ Yes ○ No
2. Are you concerned that the history may not be consistent with the injury or illness?	○ Yes ○ No
3. Are any of the following findings present on physical examination? a. Any bruise, scalp, or extremity swelling in a nonmobile child. (If you can't cruise, you can't bruise) b. Any burn, facial, or mouth injury in a nonmobile child (includes: subconjunctival hemorrhage, frenulum or palate injuries) c. Multiple bruises or any bruising in a location other than the forehead, pretribal regions, or over bony prominences (e.g., cheeks, ears, neck, torso, genitalia, upper arms, hands) d. Burn or bruise in the shape of an object	○ Yes ○ No
4. Are there findings that might reflect poor supervision, care, nourishment, or hygiene?	○ Yes ○ No
5. Are there any additional comments or concerns?	○ Yes ○ No

***ALL CHILDREN < 4 years of age must be undressed completely.**

■ **Figure 18-5: Elder Mistreatment Screening and Response Tool.** Utilizing a vetted tool assists the clinician with identifying potential abuse or neglect in the older trauma patient. If screening is undertaken, it is important that referral resources are also available.

ELDER MISTREATMENT SCREENING AND RESPONSE TOOL (EM-SART)


Brief Pre-Screen:
Positive response to one or more questions and/ or concerns based on observations?
No
ED care as usual
Yes
Proceed to Full Screen

Ask the patient:

Has anyone close to you harmed you?	○ Yes	○ No
Has anyone close to you failed to give you the care that you need?	○ Yes	○ No
Has anyone tried to force you to sign papers or use your money against your will?	○ Yes	○ No

Look for red flags;

If available, the patient's medical history includes:

Repeated visits to the ED	○ Yes	○ No
Frequent or unexplained injuries	○ Yes	○ No
History or signs of cognitive impairment	○ Yes	○ No
Delayed attention to or unmet health needs	○ Yes	○ No

The patient appears to:

Have physical signs of mistreatment (e.g., suspicious wounds, concerning personal hygiene, malnutrition, or dehydration)	○ Yes	○ No
Have unmet mental health needs or problems with substance use	○ Yes	○ No
Lack access to need resources	○ Yes	○ No
Feel uncomfortable with their caregiver(s)	○ Yes	○ No

If present, the caregiver appears:

Unengaged, inattentive, or to lack knowledge of the patient's medical needs	○ Yes	○ No
Dismissive of, frustrated with, or hostile toward the patient	○ Yes	○ No
Overly concerned or anxious about the patient	○ Yes	○ No
To have unmet mental health needs or problems with substance use	○ Yes	○ No
To lack access to needed resources	○ Yes	○ No

Record additional notes and recommendations:

○ I recommend the *EM-Full Screen.*

○ I recommend *ED care as usual.*

Notes: ____

____

CHAPTER SUMMARY

Injuries are mostly preventable events. Practical frameworks such as the Three Es are readily available to support trauma care clinicians in gathering injury context information, providing a careful handoff during patient transfer, and identifying locally relevant injury prevention priorities. Clinicians are in a privileged role that provides unique and valuable information that can be used to prevent future injuries at both the individual and population levels.

KEY LEARNING POINTS

- **Remember that trauma/injury is NO accident! Most trauma and injuries are preventable.**
- **Front-line trauma clinicians are in a unique position to contribute to injury prevention efforts locally, regionally, and nationally.**
- **Learn about the injury context for patients once it is safe and feasible to do so.**
- **Collecting injury data can be helpful to inform local and national prevention efforts.**
- **If your facility encounters a high volume of a certain type of injury mechanism or treats a patient population that is particularly impacted by injury, consider targeted injury-prevention interventions.**
- **When screening for risk factors, clinicians should ensure that options for referral are available to the patient.**

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19

Trauma-Informed Care and Social Determinants of Health

OBJECTIVES

After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Characterize social determinants of health (SDOH) and trauma-informed care (TIC)
2. Discuss models of care that can address SDOH
3. Discuss prior trauma and traumatic stress in patients and colleagues
4. Describe potential benefit of TIC to the clinician
5. Identify aspects of a trauma-informed healthcare system
6. Demonstrate trauma-informed communication
7. Identify special populations of patients that have considerations and strategies for TIC specific to them

19

Trauma-Informed Care and Social Determinants of Health

CHAPTER STATEMENT

Trauma-informed care (also called humanistic care) recognizes that patients may present having experienced past trauma in their lives (be it physical, emotional, psychological, spiritual, or social). The trauma-informed care (TIC) principles are used to inform interactions between individuals, with the knowledge and understanding that individuals have had past life and generational experiences of trauma, and promotes environments of healing and recovery rather than practices and services that may inadvertently retraumatize. TIC also recognizes that clinicians can experience secondary and vicarious trauma from witnessing suffering. Trauma-informed practices include education and protocols that improve individual and organizational culture to enhance the well-being of all involved in the healthcare interaction. Social Determinants (also called Social Drivers) of Health have a major impact on health, quality of life, and ability to thrive. The complete care of injured patients and their families incorporates a trauma-informed approach and understanding of the Social Determinants/Drivers of Health.

CASE SCENARIO

Prehospital report of a trauma activation:

- Mechanism: 25-year-old man shot in left lower extremity
- Injuries: Two gunshot wounds in left thigh
- Signs: Vital signs within normal limits
- Treatment: Pressure dressing applied

Upon arrival to the emergency department and initiation of the primary survey, the patient is sitting up saying, "What are you doing? What is going on?"

A physician responds loudly with, "Calm down and lay down, we need to examine you." The patient appears to be more agitated and begins to rip off the telemetry leads being placed. Seeing him resisting, the charge nurse announces that they are going to get the soft restraints.

The supervising physician walks in, introduces themself to the patient, and asks for the patient's name. They then proceed to tell the patient what is happening around him and why these actions are important to take care of him.

The patient relaxes and says, "Well, I was here a year ago and nobody listened to me. I got discharged too early and couldn't get to my follow-up appointment. I have had enough trauma in my life. I don't need to come to the hospital to have people cut off my clothes and do things to me without permission."

The supervising physician responds, "I'm really sorry that happened. You're my responsibility right now. Give us one more chance to do right by you. I will tell you everything that's going on, and you let me know if you have questions or concerns. If you need to be admitted to the hospital, we will make sure everything is set up for you before you leave. Right now, let's get you some pain medicine and check if you have any serious injury from being shot. Is that OK?"

The patient agrees. "Alright, one more chance, doc." The primary and secondary survey resume with his full cooperation without the need for physical or chemical restraints.

INTRODUCTION

The brief intervention described in this Case Scenario section illustrates trauma-informed care (TIC) and the psychological impact it can have on patients and clinicians. This scenario demonstrates an approach that fosters a trusting relationship between patient and clinician. In addition, clinicians should address barriers patients may have to participating in their own care, as well as risk factors for injury. The *social determinants of health* (SDOH; also referred to as the *social drivers of health*) are contributory. This chapter will highlight the importance of treating patients with an understanding of how their lived experience may impact their presentation to the trauma bay and how clinicians can approach patients in a humanistic manner while not missing a beat in injury care.

THE SOCIAL DETERMINANTS OF HEALTH (SDOH)

The SDOH are primarily grouped into five domains:

- Built environment
- Economic stability
- Education (access and quality)
- Healthcare (access and quality)
- Social and community context

Individually, each domain affects a wide range of health outcomes. Collectively, a synergistic effect is seen across domains. **In other words, multiple adverse SDOH can result in exponentially worse health. With a public health lens, addressing the social determinants that increase risks and morbidity of traumatic injury offers the most effective potential solutions for harm reduction.**

Recently, there has been increasing awareness and promulgation of efforts to identify and treat individuals at risk for physical and mental health problems related to SDOH. The National Academy of Medicine released *Integrating Social Care into the Delivery of Health Care: Moving Upstream to Improve the Nation's Health* in

2019, which recommended the “5 As”: Awareness, Adjustment, Assistance, Alignment, and Advocacy. This resulted in the adoption of social risk screening in primary care and inpatient care settings. Screening for adverse childhood experiences (e.g., exposure to trauma, abuse, or household dysfunction) and protective childhood experiences (e.g., social support and health promotion) offers insight into past and present trauma, as well as social factors that are protective of a healthy lifestyle. Other social screens address food insecurity, poverty, housing stability, racism, discrimination, and more. Barriers to widespread adoption of social risk screening include lack of resources to address issues revealed by the screening.

Born out of need to provide organizations and surgeons with the tools to identify and address the root causes of trauma, the American College of Surgeons Committee on Trauma formed the Improving Social Determinants to Attenuate Violence (ISAVE) workgroup. ISAVE is a multidisciplinary group of medical, public health, law enforcement, and community experts that endorses TIC, integration of social care (including risk screening), investing in at-risk communities, and advocacy. There remain vast opportunities for trauma centers and medical professionals to expand care beyond physical injury and to incorporate social, emotional, and psychological well-being into healing.

THE NATURE OF TRAUMATIC STRESS

Our SDOH and prior lived experiences mold our natural response to stress. Where one person may respond to stress by shutting down, another may respond by lashing out. Those who care for trauma patients and interact with their families cannot presume that others will react to a situation in the way one might themselves. **In order to implement a trauma-informed approach to patient care, trauma clinicians must recognize that patients and loved ones may present with preexisting heightened responses to traumatic events.**

The ideal trauma system would have the appropriate resources to screen and treat mental health concerns that are more commonly seen in our patient population. This section will address common screening and diagnostic tools trauma clinicians may use to identify those at risk of experiencing post-traumatic stress responses and some common nuances one might encounter.

Note: Understanding that many trauma clinicians are constrained in terms of time, ancillary personnel, and outpatient support, the tools discussed here were selected for ease of implementation. Each individual clinician must exercise clinical judgement on when and how to screen patients for psychological injuries based on one’s own resources. It may not be in the best interest of patients to screen for injuries for which no treatment resources are available. While these tools have been validated, note that these assessments care are limited by the accuracy of patient responses. Thus, building rapport with patients and families is paramount.

The Primary Care Post-Traumatic Stress Disorder for DSM-5 (PC-PTSD-5) screening tool (■ **Box 19-1**) is simple, rapid, and commonly used as an initial screen for those who may need further evaluation. It addresses the most commonly seen symptoms of a severe stress response. It is a five-question survey where the respondent can answer yes or no, with the likelihood of having significant PTSD increasing with the number of questions answered in the affirmative.

■ **Box 19-1: The Primary Care Post-Traumatic Stress Disorder for DSM-5 Screening Tool.** The Injured Trauma Survivor Screen (ITSS) is a validated tool that may be used to identify those at risk for post-traumatic psychological stress so that appropriate referrals and support may be offered.

Primary Care Post-Traumatic Stress Disorder 5 (PC-PTSD-5) Screen Tool

In the past month, have you...

1. Had nightmares about the event(s) or thought about the event(s) when you did not want to?	○ **No**	○ **Yes**
2. Tried hard not to think about the event(s) or went out of your way to avoid situations that reminded you of the event(s)?	○ **No**	○ **Yes**
3. Been constantly on guard, watchful, or easily startled?	○ **No**	○ **Yes**
4. Felt numb or detached from people, activities, or your surroundings?	○ **No**	○ **Yes**
5. Felt guilty or unable to stop blaming yourself or others for the event(s) or any problems the event(s) may have caused?	○ **No**	○ **Yes**

Trauma psychologists at the University of Wisconsin have developed and validated a similar but more intensive screening tool to evaluate the risk of both PTSD and depression in the injured patient called the Injured Trauma Survivor Screen (ITSS). This addresses a broader spectrum of psychological response to injury and can be used during an initial hospital encounter after a trauma (■ **Box 19-2**).

These tools and others like them are useful in identifying those most at risk for significant psychological trauma; however, definitive diagnosis as prescribed by the *Diagnostic and Statistical Manual of Mental Disorders*, *Fifth Edition* (DSM-5) is beyond the scope of this text and should be performed by a credentialed clinical psychologist, psychiatrist, or other qualified mental health professional.

■ **Box 19-2: Injured Trauma Survivor Screen.** The ITSS is a validated tool that may be used to identify those at risk for post-traumatic psychological stress so that appropriate referrals and support may be offered.

INJURED TRAUMA SURVIVOR SCREEN (ITSS)			**Yes = 1 No = 0**
Before this injury	**PTSD**	**DEP**	**Total**
1. Have you ever taken medication for, or been given a mental health diagnosis?	N/A	○ Yes ○ No	______
2. Has there ever been a time in your life you have been bothered by feeling down or hopeless or lost all interest in things you usually enjoyed for more than 2 weeks?	N/A	○ Yes ○ No	______
When you were injured or right afterward			
3. Did you think you were going to die?	○ Yes ○ No	○ Yes ○ No	______
4. Do you think this was done to you intentionally?	○ Yes ○ No	N/A	______
Since your injury			
5. Have you felt emotionally detached from your loved ones?	N/A	○ Yes ○ No	______
6. Do you find yourself crying and are unsure why?	N/A	○ Yes ○ No	______
7. Have you felt more restless, tense, or jumpy than usual?	○ Yes ○ No	N/A	______
8. Have you found yourself unable to stop worrying?	○ Yes ○ No	N/A	______
9. Do you find yourself thinking that the world is unsafe and that people are not to be trusted?	○ Yes ○ No	N/A	______
≥2 is positive for PTSD risk **≥2 is positive for depression risk**		**SUM =**	______

THE TRAUMA-INFORMED CARE APPROACH

TIC is a theoretical framework that recognizes that patients and clinicians bring prior experiences to any encounter and to the system as a whole. In some parts of the world, TIC may also be referred to as "humanistic care."

As a service delivery model, TIC is founded on knowing that the best quality care is delivered when clinicians and healthcare systems holistically understand patients' SDOH and preexisting psychological injuries. The components of TIC are encompassed by the four **R**s:

- **Realizing** the widespread impact of trauma
- **Recognizing** the signs and symptoms of trauma
- Creating a system that can **Respond** to trauma
- Avoiding **Retraumatization**

The successful creation of a system that is trauma informed involves integration of these components into both clinical care and the system of care itself. There are six key principles of the trauma-informed approach, as described by the Substance Abuse and Mental Health Services Administration's guiding principles of trauma-informed care:

- Safety
- Trustworthiness and transparency
- Peer support
- Collaboration and mutuality
- Empowerment, voice, and choice
- Cultural, historical, and gender issues

Using these principles to provide TIC is of benefit to patients, families, and healthcare workers.

Experiencing a traumatic event, being brought to a trauma bay filled with strangers and fully exposed, can understandably lead to loss of sense of control, predictability, and perceived safety. TIC includes reassurance through open, direct communication and reduction of overstimulation. This may be achieved by having a point person for communication during the primary, secondary, and tertiary Surveys, by giving the patient access to their phone, or helping them sit up (if safe) so they can look out and see what is happening around them and to them.

Further, TIC does not end at discharge. Barriers to follow-up care need to be addressed by creating a plan *with* the patient for achievable goals. The family of a patient will also benefit from TIC through respectful interactions, as well as thoughtful physical layout of waiting rooms and accommodations for staying overnight with their loved one. TIC is as simple but deliberate as a clean and safe place for family to sit with access to tissues, water, and bathrooms.

A truly trauma-informed system executes intentional training and has plans for space allocation written into hospital policy. It is exemplified by a society based on justice, equal opportunity, and love for one another; with TIC, clinicians treat patients and loved ones with empathy and respect.

TRAUMA-INFORMED COMMUNICATION

Trauma-informed communication begins with an understanding that all people have experienced trauma in their lives. Our communication with our patients and team therefore reflects this understanding as it fosters a safe and welcoming environment, increases engagement, and improves collaboration. Fundamentals of trauma-informed communication are described in ■ **Table 19-1.**

Establishing rapport with a patient during the initial trauma resuscitation phase sets a tone for the rest of the hospitalization. Nonverbal communication and body language are just as important as verbal communication. Each individual team member has the potential to impact individual patient experience. Individuals brought into the hospital after an injury are at times met with negative stigma from staff, particularly victims of violence. Staff should refrain from any preconceived judgements and sarcastic comments. The trauma team should strive to create a safe healing environment, which benefits both the patient and team.

The atmosphere surrounding a trauma evaluation can be chaotic. Being able to recognize bias and prior trauma while omitting negativity from our communication can help establish trust. When a patient is hemodynamically unstable, minimal communication may occur with them. If the patient is stable, however, provide a brief introduction, explain why they are in the hospital, and give them an expectation of what will come. Attempt to provide nonjudgmental, empathetic, and genuine interactions. Ask the patient open-ended questions such as, "Do you remember what happened to you?" Let the patient know what is coming next in the evolution of the care they are receiving. If and when you have time, ask your patient questions; this not only conveys respect but may improve their comfort and sense of control.

For the person perceived as being uncooperative, attempt to redirect them. Ask them about how to make the situation better for them. For agitated individuals, try asking them, "What can I help you with?" instead of escalating a situation by using phrases such as, "Stop," "You can't do that," or "If you continue, you will be restrained." A patient who is resisting can be approached by saying, "I understand that this may be difficult for you; however, I have to perform a physical exam and that means I have to touch you. This is to find out if you have any serious injuries and how we can help you."

For patients who are unresponsive verbally but awake and alert, try saying, "I respect your right not to answer me. I will continue my exam and explain everything I'm doing as we go along." Patients who use threatening or abusive language may be approached by clearly stating, "You just stated ___. That language is not accepted here." Trauma-informed communication includes protecting healthcare workers from behavior that violates hospital policy.

■ **Table 19-1: Fundamentals of Trauma-Informed Communication.** Trauma-informed language and communication can help build trust and rapport with patients and may assist in deescalating tense situations.

Trauma-Informed Communication		
DO	• Communicate respectfully in a normal relaxed voice • Try to invoke a sense of calm • Engage with eye contact • Positive body language • Actively listen • Ask open-ended questions • Express kindness, patience, and acceptance	**EXAMPLES:** • *"I'm Dr. X, the trauma surgeon taking care of you, and you are in the Emergency Department because you were involved in a motor vehicle crash. There is a lot going on, but we're all here to help you. Focus on my voice, and I'll walk you through what we're doing and why."* • *"What do you prefer to be called?"* • *"Is there someone you want called to let them know you're here?"*
DON'T	• Shout • Interrupt • Show or imply judgement • Make assumptions • Use sarcasm	**EXAMPLES:** • *"Stop fighting. Just calm down. We have to do this."* • *"We will restrain you."* • *"I bet they were just minding their own business."* • *"I'm sure they deserved it."*

HEALTHCARE CLINICIANS AND THE RESPONSE TO TRAUMA

Secondary trauma and vicarious trauma, while not new terms, have more recently shaped how we care for healthcare workers and specifically those staff who are exposed to traumatic experiences. Both types of trauma stem from caring for and witnessing the suffering of others. ***Secondary trauma*** is often characterized by the immediate symptoms of this exposure, including physical and mental adverse reactions. The distinct symptoms that arise (such as intrusive thoughts, avoidance of similar circumstances, or negative mood) can cause so much distress that the DSM-5 has included them within a potential diagnosis of post-traumatic stress. Thus, secondary traumatic stress is considered a professional risk factor for healthcare workers. ***Vicarious trauma*** is often described as an overall change in worldview, usually resulting from chronic and repeated exposure to the suffering of patients and others.

Medical professionals who regularly provide care to trauma victims are often the first contact with these individuals, by design. **The sheer act of witnessing the suffering or death of patients or having the necessary difficult conversations with patients and their families can cause stress. For those who specialize in trauma care, this repeated stress can lead to significant psychological injury**. In short, those who help trauma victims have the propensity to become victims of trauma themselves. Ultimately, it can impact one's feelings, emotions, worldview, self-esteem, and sense of safety.

TIC and access to resources for those impacted by secondary and vicarious trauma are crucial. There are several ways in which to mitigate the impact of trauma experienced by medical professionals. Identification of how the workload (long hours, high volume, etc.) and the social support from the work environment contribute to well-being is key. TIC includes assessing how one's own coworkers and environment can be elevated to be protective factors.

The patient is not the only one to benefit from a trauma-informed approach. Healthcare workers in trauma-informed healthcare systems report feelings of improved work satisfaction and reduction in burnout. Secondary trauma, moral injury, and burnout have heavily impacted the healthcare workforce. Connecting with our trauma care colleagues and our patients has demonstrated a reduction in these serious issues. Adopting TIC is not just about being a good clinician; it is realizing the broader sense of trauma and responding in a way that provides the tools to treat patients more comprehensively. The benefits are broadly experienced, and the positive culture change to systems of care can be profound.

■ **Table 19-2: Trauma-Informed Care in Special Populations.** Some populations may experience distinctive challenges during healthcare interactions. Understanding these challenges assists in providing humanistic, trauma-informed care.

	Special Considerations	Direct Care and Communication Strategies	System Strategies
Patients who have experienced violence	• May experience heightened fear, loss of perceived safety and control. • Can experience victim-blaming and biased treatment, which leads to distrust of healthcare system. • Presence of law enforcement can contribute to discomfort, distrust, and lack of privacy when not approved by the patient. • Increased incidences of adverse Social Determinants of Health (SDOH), substance abuse, and mental illness before and after injury. • Barriers to follow-up care and supportive services are more common than other traumatic mechanisms. • Risk of repeat injuries due to violence are higher in patients who have experienced violence.	• Introduction of team members, roles, and what is being done to the patient during their evaluation can help improve sense of safety, trust, and safety for victims of violence. • Empathetic, nonjudgmental statements: "I'm sorry this happened to you. We are here to care for you." • Keep sensitive areas of the body covered as able, especially victims of intimate partner violence (IPV) and sexual assault. • Inquire about the assault circumstances and screen for abuse in private; use normalizing language: "We want to keep you safe and help support you. Can you tell me more about what happened? Do you have a safe place to go to when you leave here?"	• Develop and disseminate protocols outlining the role of law enforcement in the healthcare setting that promote community and patient safety, family reunification, patient rights, privacy, and trust. • Implement evidence-based hospital violence intervention programs (HVIPs) or hospital-linked programs to provide comprehensive supportive services to address unmet needs, risks, and recovery. • Standardize IPV screening, develop specialized social work and forensic nursing services for IPV, elder abuse, child abuse, and sexual assault. • Identify and link patients to community- or state-based resources dedicated to victims of violence (e.g., shelters, crime victims compensation programs).
Patients with Non-English Preferred Language	• Patients may not speak the primary language used in the hospital. • May understand and speak some English, but may have difficulty discussing medical information in a noisy, stressful environment. • Are not routinely asked preferred language. • Are less likely to have comprehensive motor and sensory examinations, explanation of next steps, or reassurance. • Pain is more often undertreated during hospital care and at discharge. • Ineffective communication can cause lack of understanding of injuries, care, and discharge instructions.	• Directly inquire about patients' preferred language preference. • Utilize a certified medical interpreter for communication during trauma evaluation and care. • Avoid using family members and acquaintances for translation. • Standardize care protocols both in-hospital and at discharge so that trauma guidelines are followed for every patient including non-English speakers.	• Language interpreters available in hospital including the trauma bay improves communication, utilization, clinical outcomes, and patient satisfaction. In person is best, followed by video and phone. • Programs to certify staff in interpreter services. • Provide training on effective use of interpreter services. • Standardize discharge instructions and protocols avoid bias. Translate instructions into the most common languages spoken at the institution.

SPECIAL POPULATIONS: CONSIDERATIONS FOR TRAUMA-INFORMED CARE

While the fundamental approach to TIC is ubiquitous, there are a few populations often encountered during trauma care, that should be highlighted. ■ **Table 19-2** describes special considerations and strategies for patient care, communication, and systematic design for patients who have experienced violence, and those for whom English is not their preferred language.

BECOMING A TRAUMA-INFORMED ORGANIZATION

When an entire healthcare organization or trauma center is trauma-informed, the policies, practices, and culture of all individuals implement the principles of TIC in routine practice. Typically, there are several steps to achieve this, starting with integration into curricula such as ATLS and finding individuals within the system to "champion" the change. Stakeholder buy-in is essential and includes leadership, clinicians, security, support staff, and the community the healthcare system serves. Quality improvement programs within the hospital should include a lens on TIC. This may seem like a heavy lift, but the principles are steeped in equity care, and weaving the culture into everyday practice will seem second nature as it becomes the institutional norm. The quality outcomes for the patient, the clinician, and ultimately the system will speak for themselves.

CASE SCENARIO: CONCLUSION

The trauma care team used a trauma-informed approach during the rest of the patient's evaluation and treatment. Through collaborative discharge planning, the patient does not have the same barriers he had during his prior experience. At discharge, he states, "Doc, I'm glad I gave you all one more chance. I feel good leaving the hospital this time. I already have my bandages and pain medicine. I have a taxi voucher for my follow-up appointment, and I feel respected as a person. Thank you for understanding why I was upset last time and for talking me through the process."

CHAPTER SUMMARY

Trauma-informed care, also known as humanistic care, recognizes that many patients present with histories of previous mental, physical, and psychological trauma and reminds clinicians that interactions with the patient and the healthcare team can have a direct impact on patient experience, safety and outcomes and can impact their own well-being. Recognition of personal biases and practicing a humanistic approach to patients is trauma informed care. Healthcare clinicians can experience secondary and vicarious trauma; recognition allows them to address it, and a TIC approach can improve it. Comprehensive care is trauma-informed care; collaborating with people with different expertise can lead to addressing root causes of injury, including social drivers of health.

KEY LEARNING POINTS

- **SDOH are "conditions in which people are born, grown, work, live, and age" and can be grouped into five domains: the built environment, economic stability, education (access and quality), healthcare (access and quality), and social and community context. SDOH directly impact health outcomes for trauma patients.**

- **Traumatic stress affects people differently. Patients and healthcare workers are at risk for developing psychological injury from the trauma care experience. A trauma-informed healthcare system works to mitigate injury for all parties involved.**

- **TIC involves the four Rs: Realizing the widespread impact of trauma; Recognizing the signs and symptoms of trauma; creating a system that can Respond to trauma; and avoiding Retraumatization.**

- **Trauma-informed communication demonstrates compassion and empathy for patients, families, and colleagues while avoiding preconceived judgements and sarcastic comments.**

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20

Communicating Serious News in the Acute Trauma Setting

OBJECTIVES

After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Explain how a focused patient update and goal-setting conversation can be initiated and conducted in the acute trauma setting
2. Describe the importance of collaborative decision-making and patient autonomy in the acute trauma setting
3. Discuss the need for culturally appropriate communication as well as factors that affect communicating serious news in certain special populations and situations

20

Communicating Serious News in the Acute Trauma Setting

CHAPTER STATEMENT

Clinicians in the acute trauma setting must be prepared to communicate serious, life-altering news to patients and families. Just as having an organized, systematic approach to the medical management of a critically injured patient is crucial, communicating serious news to a patient or family should consist of preparation and a well-formulated process. A patient's preexisting wishes must be considered. Communication must also be culturally sensitive and take into account traditions and practices.

INTRODUCTION

Providers of acute care to those with traumatic injuries are generally focused on the reversal of physiologic derangement and restoration of preinjury functional status. Some injuries are incompatible with the achievement of these goals. Further, patient-centered care is the foundation of modern clinical practice, and medical dogma has shifted from paternalistic to collaborative, requiring that medical clinicians develop new communication skills and tools.

Training on how to talk about debilitating and/or disabling injuries and death is essential for trauma care. In this chapter, we outline the importance of, and approach to, having these serious conversations in an acute postinjury setting. This chapter is framed from the point of view of a discussion with a patient's family/loved ones/surrogate decision-makers, for which the word "family" will be used. This approach is done for consistency, though clearly the same principles apply for discussion with patients directly.

Cultural humility and awareness must be incorporated when using the information in this chapter. Patients and families must have a voice in how they receive information, who within the family will receive information, and how procedures (such as postmortem care) and other processes are implemented. Forthrightness, empathy, active listening, and transparency are the pillars of this type of communication, but clinicians must be prepared to adapt their approach based on patient, family, and culture-specific characteristics.

DECISION-MAKING: RELEVANCE TO INITIAL PATIENT MANAGEMENT

Before embarking on communication of serious news, it is helpful to have some idea of a patient's existing wishes. A hallmark of patient-/family-centered care is that decision-making should be shared and collaborative, with the patient's wishes taking precedence whenever possible. The presence of advance directives/portable orders of life-sustaining treatment/medical orders of life-sustaining treatment, where relevant to practice, may help clinicians understand a patient's wishes about life-sustaining therapy and other healthcare options. Quickly reviewing these documents, if they exist, will assist clinicians in rendering patient-centered, goal-concordant care, even in the acute postinjury setting. It is important to note that these documents may not be routinely available in all settings.

It is also important for clinicians to identify decision-makers/proxies/surrogates who can act on the patient's behalf if they are not able to communicate an understanding of their illness/injuries, acknowledge in their own words the risk and benefits of pursuing or declining the proposed treatments, and use this information logically. Surrogate decision-makers may be identified in a living will or advance directive. These documents may not be available in a situation of acute traumatic injury; nonetheless, clinicians should inquire about their existence.

If it is determined that the patient does not have the ability to make decisions on their own and has not previously designated a healthcare proxy, the legal next of kin is called upon to assist with medical decisions. Additionally, **there will be times when a patient does have capacity to participate in medical discussions but does not wish to participate in medical decisions. In this circumstance, it is within their rights to designate another party to do so.**

COMMUNICATING SERIOUS NEWS

Consistent with ATLS® principles, all patients should be reassessed after initial stabilization and management and prior to transfer. If the patient will not be transferred, they should be reassessed again within 24 hours of hospital admission. These clinical reevaluation points provide convenient opportunities for family updates; families should also be updated whenever there is a significant change in clinical status.

There are multiple ways to approach serious news conversations. Several published blueprints for sharing bad news exist in the palliative care literature, including the Setting, Perception, Invitation, Knowledge, Empathy, Summarize (SPIKES) Protocol; the Reframe, Expect emotion, Map out patient goals, Align with goals, Propose a plan (REMAP) goals-of-care conversation; and an Activating event or situation, Beliefs, Consequences, Disputation of the beliefs, Effective new approach (ABCDE) model. Regardless of the specific model chosen, there are **four key concepts** that apply in this process (■ **Figure 20-1**).

■ **Figure 20-1: Four Key Concepts: When Communicating Serious News.** When speaking to patients or families about serious news, it is important to be prepared: have a clear message, make sure the environment is suitable, and make sure all the appropriate team members are present. During the meeting, do as much listening as talking. Afterward, debrief with the team.

1

Organize your thoughts

Think about a "warning." (I have serious news to share with you.)

Follow with a "Headline" statement. What are the most serious injuries and what is their expected impact?

2

Prepare for the meeting

Determine which team members will be present.

WIll an interpreter be needed?

Be aware of your appearance.

Select a comfortable, private setting.

Make sure there is enough space so that all can sit and be at "eye level."

3

Meet with the family (ABCDE)

- A Ask what the family has been told.
- B Begin with the warning.
- C Concise summary.
- D Do allow for silence. Don't speak too much. Listen!
- E Enourage and validate Emotions. Elicit questions. End Encounter with a plan for next steps.

4

Debrief with the team

Ensure all team members know the details of the meeting and plans for next steps.

Try to arrange for opportunities for team members to explore and manage their own emotions.

KEY CONCEPT #1: ORGANIZING YOUR THOUGHTS

Trauma cases are often complex, with multiple injuries affecting the patient's status and prognosis. Just as the primary survey requires identifying and prioritizing the most life-threatening injuries, clinicians can use a similar approach to organizing how they will communicate with a family. By determining which are the most impactful injuries a patient has sustained and how they impact the patient's status and expected clinical course, a "Headline" statement can be formulated.

"HEADLINE = FACT + MEANING"

Consider a patient with multiple injuries including a high-level cervical spinal cord injury as an example: A clinician may determine that the most serious injury is the C-spine injury. The **"Fact" involves the clinical detail of the injury** (e.g., level). The **"Meaning" involves the impact of this injury** such as the need for intubation, the inability of the patient to walk and move their arms/legs, and the probable need for prolonged (and possibly repeated) hospitalizations, among others. While not all of these issues will necessarily be part of the "Headline" statement, it might begin with:

"I'm afraid I have some serious news to discuss with you. Your daughter has had an injury to her spinal cord in the neck which is interfering with her breathing. We are going to have to put a tube in her throat to help her breathe."

Other details about the impact and meaning of the injury may be communicated as well, depending on the progress of the conversation. **The most important concept is that intentional preparation by the trauma clinician is required.** Disclosure of news related to significant disability or death from traumatic injury is often performed when the clinician has had little to no time to build a relationship with the patient or family, and it often occurs in a chaotic and time-constrained clinical setting. **Taking even a few moments to make sure that thoughts are organized beforehand and ensuring that the language used avoids jargon and is easy for the family to understand will save time and stress in the end. Improvisation in such cases is rarely effective.**

KEY CONCEPT #2: PREPARING TO MEET WITH THE FAMILY

In addition to organizing your thoughts, consideration should be given to setting, appearance, what team members should be involved, and making sure that everyone is clear what the goal will be for the discussion. A "What-Where-Who-How-Why" model could be used (■ **Figure 20-2**).

As much as possible, interruptions should be minimized, and body language should not unintentionally give the impression of impatience; the family should feel that the discussion is as important to the healthcare team as it is to them. Consultants who can lend additional perspectives can also be helpful in clarifying expectations, but the details of what will be conveyed to the family should be agreed upon prior to the meeting to minimize confusion and surprises. Ideally, the conversation should take place in an area large enough to allow all participants to sit and face each other at eye level. If interpreters are necessary, they should be professionally trained, as opposed to being other family members; this ensures correct translation of any medical terminology and removes stress from the family member who might act as the interpreter in less formal settings.

■ **Figure 20-2: Preparing to Meet With a Family or Patient.** Using a checklist, like that illustrated in this Figure, can help the clinician prepare for the meeting.

WHAT

This begins with the warning and Headline statements: preparing for communication of serious news and what will be the most important pieces of information relayed.

WHERE

- ○ Is the discussion space private, clean, and welcoming?
- ○ Are water and tissues available?
- ○ Is there egress should the situation become unsafe?

WHO

- ○ Which of the Team members will be present?
- ○ Is an interpreter needed?
- ○ Will a Social Worker or Spiritual Care Specialist be present?
- ○ Who will be present from the patient's support system?

HOW

This is how you and your Team are presenting yourself.

- ○ Are your clothes appropriate (e.g., nonbloody)?
- ○ Are you able to be at eye level with the family (ideally all seated)?

WHY

This involves the goal of the discussion.

- ○ Is it an update only?
- ○ Are there decisions that must be made?

Some clinicians may be concerned about the safety of their team as well as the family. The suddenness of the traumatic event and hearing serious news may catch the family off guard or unprepared. The information often generates intense emotional reactions that may range from shock to anger. Having a strategy to exit should the physical space become unsafe is useful. For example, keeping the door to the room open and unblocked when delivering news to a large group and sitting close to the door may help. Clinicians should work with their institutions to develop protocols to manage such situations.

KEY CONCEPT #3: MEETING/ COMMUNICATING WITH THE FAMILY

Tyrie et al describe **an "ABCDE" communication algorithm that may be used during a family meeting at which serious news is discussed:**

A= Acquaint yourself with the family/Ask

A good way to begin the conversation after making introductions is to ask an open-ended question, such as, "What have you been told about what has been going on?" Allowing the family to describe in their own words their understanding will provide a foundation for ongoing discussion. This is an opportunity for the clinician to mainly listen. It may also be appropriate at this "Ask" stage to ascertain if the patient has an existing advance directive or if they have communicated any wishes regarding life-sustaining therapy

B = Begin with a warning

As mentioned above, starting the "Headline" statement with "I have serious news to share with you" alerts the family and sets the stage for the conversation.

C = Concise summary

When delivering serious news, clinicians may be anxious and revert to communicating using a plethora of details and medical jargon. This style of communication can be overwhelming and incomprehensible to the patient/family such that the main message gets lost in translation. This is why prior preparation of the "Headline" statement is so useful. Particularly when the news may be associated with poor prognosis, "headline" the most serious injury. Resist the tendency to catalog every injury in the initial meeting; family will need time to digest information. **Focus on the "Fact" and especially the "Meaning" of the most serious diagnosis and how this injury will impact the patient's big-picture condition**. Do they have brain damage or paralysis? Will they survive?

Clinicians should try to avoid being overly optimistic or paint information more favorably than is realistic when communicating serious news and poor outcomes. Keep in mind that attempts to soften the message may result in inadvertent miscommunication, which can itself result in mistrust between patients/families and clinicians. The goal is to provide the truth, as far as it is known at that time, about the nature of the patient's injuries and anticipated course, regardless of how hard it is to hear.

When communicating news of death, recognize that there is no way to soften this news; maintaining clarity with use of the "D" word (died, dead) is extremely important. Communicate news of the death first after a brief narrative (one sentence) that provides context that the family can understand, and then add other details. Like any serious news, disclosures of death should be preceded with a warning. A sample script may look something like, "I have very serious news to share with you. Your ____ was in a car crash with major injuries to his heart and brain. We tried everything we could; he **died** a few minutes ago...."

D = Do use silence/Do not speak

Once you have communicated the news, pause for 10–15 seconds; this allows the patient/family to process what was just said and react. A common error in this setting is to begin speaking too soon to fill the silence; patients/families need time to process. Let them begin to speak to break the silence.

E = Encourage and validate emotions/Elicit and answer questions/End Encounter

Inevitably, sharing difficult news will provoke a wide range of emotions. Patients and families may or may not be ready to communicate how they feel. Remember that providing space for emotion to be felt by lending silence communicates empathy. If the patient/surrogate is too emotional to continue, it may be best to take a short break, allow space for family members to briefly discuss the news they have just received, and revisit the conversation a short while later. Ensure that the family knows how to reach the primary clinician or other member of the healthcare team so they do not feel deserted. Alternatively, prearrange a follow-up time for discussion.

When revisiting a delicate conversation, various communication tools may come in handy. The mnemonic NURSE; Name, Understand, Respect, Support, Explore, is a commonly used framework for addressing emotions (**■ Figure 20-3**).

■ Figure 20-3: NURSE Mnemonic for Empathetic Communication. The NURSE communication tool provides a framework for communication that can help the clinician address and explore patient and family emotions in an empathetic manner.

N.U.R.S.E.	
Name	*“It sounds like you’re worried about experiencing pain.”*
Understand	*“My understanding of what you are saying is that you’re afraid of what this means for your family.”*
Respect/Reassure	*“I will respect your courage to be vulnerable in this moment.”*
Support	*“I will be with you through this process.”*
Explore	*“It seems like you’re upset, can you tell me about what you’re feeling.”*

For example, “As I listen, it sounds like you are worried/scared/anxious about x/y/z. Would you mind sharing more about that?” By acknowledging the family’s emotions, the clinician creates an open and supportive atmosphere, which communicates an alliance. It is also important to note that questions are often based in unaddressed emotions, and when responding to questions, it is important to address not only the cognitive but also the emotional underpinnings of the questions.

When ending the encounter with the family, the clinician should make certain that the family is clear about the plans going forward. It is helpful to summarize the conversation and provide time for questions. It is important to note that the goal is not necessarily to have a complete understanding of all potential futures. In the initial phases of trauma care, there are many unknowns. Perhaps the best example of this is the recovery trajectory after traumatic brain injury, a clinical entity with a varied and unpredictable course. If death is a likely outcome with progression of a particular injury, this should be disclosed.

The name and contact information for the responsible surrogate/family member should be confirmed. As stated previously, the family should also know how to contact the healthcare team if they have any additional questions.

KEY CONCEPT #4: DEBRIEFING WITH THE TEAM

Given the nature of the acute trauma setting, consideration should be given to how best to achieve a team debriefing, particularly if multiple disciplines are involved. While an in-person debriefing in real time is ideal, alternative structures may be necessary. However the debrief is accomplished, it should include the following:

- Content of disclosure: In the same way that critical clinical information is included in the patient handoff to the next phase of care, information about what was discussed at the family meeting is a crucial part of the debrief. Whether or not an in-person team debrief is possible, a summary in the chart detailing who was present at the family meeting, what was said, and agreed-upon future steps is essential. If the patient is being transferred to another facility, a copy of this should accompany the patient in transport.
- The name and contact details for the patient’s proxy and any advance care planning documents should be accessible to the healthcare team (and accompany the patient if being transferred).
- Treatment goals: What is the family’s understanding of the expected clinical course? What are the next steps, including the next planned meeting with the family? What support systems are in place (or need to be established) for the family?

One of the important advantages of a structured, in-person debriefing is the opportunity to allow clinicians to discuss and explore their own emotions. This is especially important following an intense and/or unsuccessful resuscitation. As the trauma team leader, it is important to recognize the emotional toll that caring for a severely injured trauma patient takes on all those involved. Planning for structured debriefings to run immediately after the patient has either stabilized, died, or transferred will allow all those involved to begin to process the potentially overwhelming emotions that caring for these patients can bring up.

In order to have a team that is ready, willing, and able to care for the next severely injured patient, the trauma team leader should take the time to facilitate these debriefings whenever possible. The nature of trauma care may not allow immediate debriefings or for all disciplines to always attend; the team leader should engage the system to arrange for team- and clinician-centered follow-up. Some specialists, such as social workers, spiritual care professionals, and mental health counselors, may prove particularly useful. Some sites perform routine debriefing that is focused on process or quality improvement. **While this is critical to optimizing patient care, it is equally important to patient care that clinicians have an opportunity to focus on how a resuscitation has emotionally affected them.**

CULTURALLY APPROPRIATE CARE AND PROCESSES

Culturally appropriate care may require the clinician to consider a myriad of aspects, including ethnic heritage and religious traditions, gender identity, and local or even family-specific practices. As mentioned in the introduction, clinicians may need to adapt their approach to communication bearing this in mind. They should encourage the family to communicate their important cultural traditions to the healthcare team. An important example of this would be understanding and incorporating culturally appropriate postmortem care practices when a patient dies in the acute trauma setting.

SPECIAL POPULATION CONSIDERATIONS

THE PEDIATRIC PATIENT

Disclosing to parents the serious injury or death of a child is perhaps the most difficult conversation imaginable. Following the Four Key Concepts and ABCDE communication framework presented in the chapter can potentially help mitigate some of the intense immediate and long-term psychiatric stress associated with receiving such news. If serious news is disclosed with respect, sensitivity, and an expressed understanding of the significance of the news imparted, the parents tend to be grateful for the care rendered by the involved staff.

THE PREGNANT TRAUMA PATIENT

Navigating the disclosure of fetal loss is difficult for many clinicians in the acute postinjury setting but remains a top concern for the pregnant trauma patient. The basic tenets of disclosing death apply to this scenario. Parents value empathy and kindness. Importantly, terms such as "products of conception," "embryo," and "fetus" are generally not well-received, as parents generally talk about their "baby" from the beginning of pregnancy. Thus, the term "baby" is preferred. If the sex of the baby has been determined, use of appropriate pronouns is also recommended.

THE OLDER ADULT

Patients who are in the later phases of life are more likely than other patients to have established beliefs about limitations on care at the end of their life, and these should be elicited. Independence, recovery time, and return to functionality are also critical to evaluate and communicate if they are known at the time of acute treatment. However, clinicians should be mindful that prognostic recovery is rarely determined by age alone and avoid allowing ageism to influence their clinical decisions and communication with the care team, patients, and their families.

MASS CASUALTY SETTINGS

In circumstances where multiple patients present from the same incident, one important consideration is confirmation of patient identity before disclosing serious news. In addition, the clinician may be called upon to manage multiple concerned families simultaneously and must maintain the privacy of each patient. Additional details can be found in *Chapter 17, Triage and Disaster Management.*

CHAPTER SUMMARY

Providing updates and having goal-setting discussions with patients and families early in the hospital course is an essential part of modern, high-quality trauma care. Recognizing that there are many unknowns in the first few hours after injury, clinicians should remember that it is not necessary to provide a comprehensive overview of all potential futures. The goal in the first update is to provide a reasonable assessment of the patient's status, support and engage patients and their families as they respond to the injury, and begin to outline treatment goals and any limitations to treatment that the patient may have. The **Four Key Concepts** and the **ABCDEs of trauma communication** outlined in this chapter can provide a useful framework for preparing for, implementing, and processing these conversations. If the patient will be transferred to a different unit or facility, details of these conversations, summaries of the patient's/family's stated goals, information about surrogate decision-makers, and advanced care plans are as important as information about the physical injury and should accompany the patient in transport. Patient-/family-centered trauma care encompasses the whole person and their family. By engaging in thoughtful, compassionate, and timely communication with patients and their families, we help them cope with what is happening to them in the present and prepare for the future.

KEY LEARNING POINTS

- **A focused patient update and goal-setting conversation is an essential part of high-quality trauma care and should be accomplished as soon as possible after initial assessment and stabilization and whenever there is a significant change in the patient's status.**
- **Preparation for meetings that will involve communication of serious news is critical and will help avoid misunderstandings and mistrust.**
- **Using a "Headline" statement preceded by a warning ("I have serious news to share with you") can help the clinician set the tone for the ensuing discussion.**
- **Using the ABCDEs of communication during a family meeting provides a useful guide for the clinician and can aid them in conducting a meaningful and empathetic discussion.**
- **Details about family communications should be documented and shared with the team, including: what was discussed, what the family knows, who participated, who is the primary surrogate (and their contact information), what the stated goals are, and whether any limitations to care have been established. These details should accompany the patient if they move to another phase of care.**

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SECTION III

Specific Injuries and Injury Patterns—Special Considerations

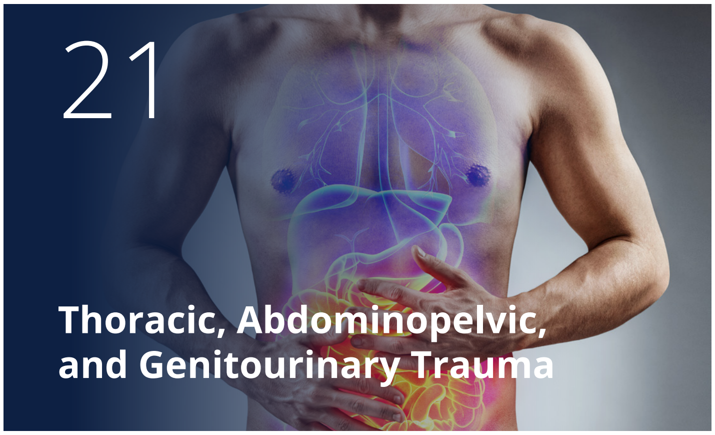
Chapter 21: Thoracic, Abdominopelvic, and Genitourinary Trauma **289**
Chapter 22: Penetrating Trauma **305**
Chapter 23: Ocular Trauma **317**
Chapter 24: Injury in Combat Zones and Austere Environments **327**

21

Thoracic, Abdominopelvic, and Genitourinary Trauma

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Identify the anatomic regions of the chest, abdomen, and pelvis that are critical in assessing and managing trauma patients
2. Recognize a patient who is at risk for chest, abdominopelvic, and/or genitourinary injuries based on the mechanism of injury
3. Identify patients who require surgical consultation and possible operative and/or catheter-based intervention
4. Use the appropriate diagnostic procedures to determine if a patient has ongoing thoracic, abdominal, and/or pelvic hemorrhage, and/or other injuries
5. Describe the acute management of thoracic, abdominopelvic, and genitourinary injuries



21

Thoracic, Abdominopelvic, and Genitourinary Trauma

CHAPTER STATEMENT

Unrecognized chest, abdominal, and pelvic injuries continue to cause preventable death. Significant blood loss can be present in the thoracic cavity, abdominal cavity, or retroperitoneum without a dramatic change in the external appearance or dimensions of the abdomen and without signs of peritoneal irritation. Any patient who has sustained injury to the torso from a direct blunt, deceleration, blast, or penetrating injury is considered to have a thoracic visceral, abdominal visceral, vascular, or retroperitoneal/pelvic injury until proven otherwise. Rupture of a hollow viscus and bleeding from a solid organ or the bony pelvis may be challenging to recognize.

INTRODUCTION

The assessment of circulation during the primary survey includes early evaluation for possible torso hemorrhage following trauma. The mechanism of injury, injury forces, location of injury, and hemodynamic status of the patient determine the priorities and best method of thoracic, abdominopelvic, and genitourinary assessment.

ANATOMY

Anatomy of the chest is reviewed in *Chapter 5, Breathing and Ventilation Assessment and Management*. Superiorly, the thoracoabdomen is bounded by the nipple line anteriorly and the infrascapular line posteriorly. Inferiorly, it is bounded by the costal margins. Thoracoabdominal structures include the diaphragm, liver, spleen, and stomach. These are somewhat protected by the bony thorax. **Because the diaphragm rises to the level of the fourth intercostal space during full expiration, fractures of the lower ribs and penetrating wounds below the nipple line often injure the abdominal viscera**.

The abdominal structures are partially enclosed by the lower thorax. The anterior abdomen is defined as the area between the costal margins superiorly, the inguinal ligaments and symphysis pubis inferiorly, and the anterior axillary lines laterally. Most of the hollow viscera are at risk when there is an injury to the anterior abdomen.

The back is the area located posterior to the posterior axillary lines from the tip of the scapulae to the iliac crests. This includes the posterior thoracoabdomen. The flank is the area between the anterior and posterior axillary lines from the sixth intercostal space to the iliac crest. Musculature in the flank, back, and paraspinal region acts as partial protection from visceral injury.

The flank and back contain the retroperitoneal space. This potential space is the area posterior to the peritoneal lining of the abdomen. It contains the abdominal aorta; inferior vena cava; most of the duodenum; pancreas; kidneys and ureters; the posterior aspects of the ascending and descending colon; and the retroperitoneal components of the pelvic cavity. Injuries to the retroperitoneal visceral structures are difficult to recognize because they occur deep within the abdomen and may not initially present with signs or symptoms of peritonitis. In addition, the retroperitoneal space is not sampled by diagnostic peritoneal lavage (DPL) and is poorly visualized with FAST (focused assessment with sonography in trauma).

The pelvic cavity is the area surrounded by the pelvic bones, containing the lower part of the retroperitoneal and intraperitoneal spaces. It contains the rectum, bladder, ureters, iliac vessels, and internal reproductive organs. Significant blood loss can occur from injuries to organs within the pelvis and/or directly from the bony pelvis. ■ **Figure 21-1** illustrates thoracoabdominal anatomy.

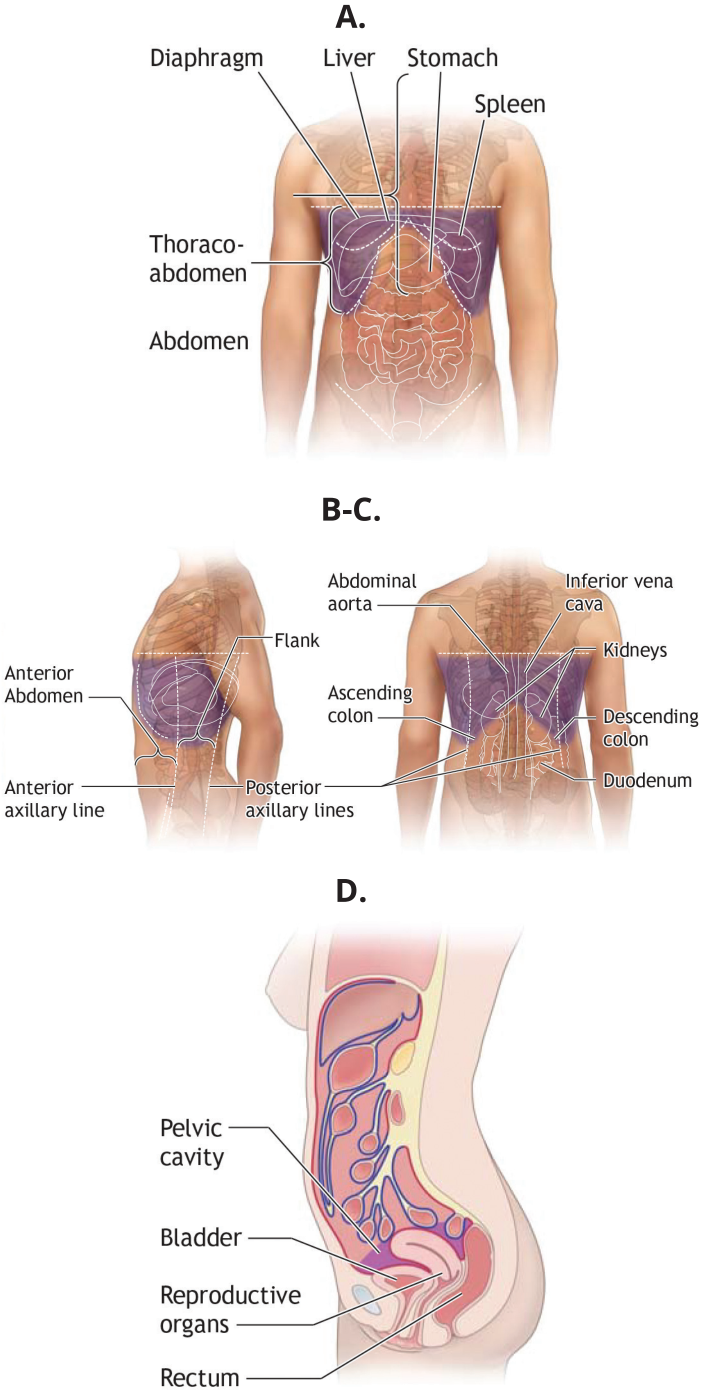
MECHANISM OF INJURY

Consideration of the mechanism of injury facilitates the early identification of potential injuries, directs which diagnostic studies may be necessary for evaluation, and identifies the potential need for patient transfer.

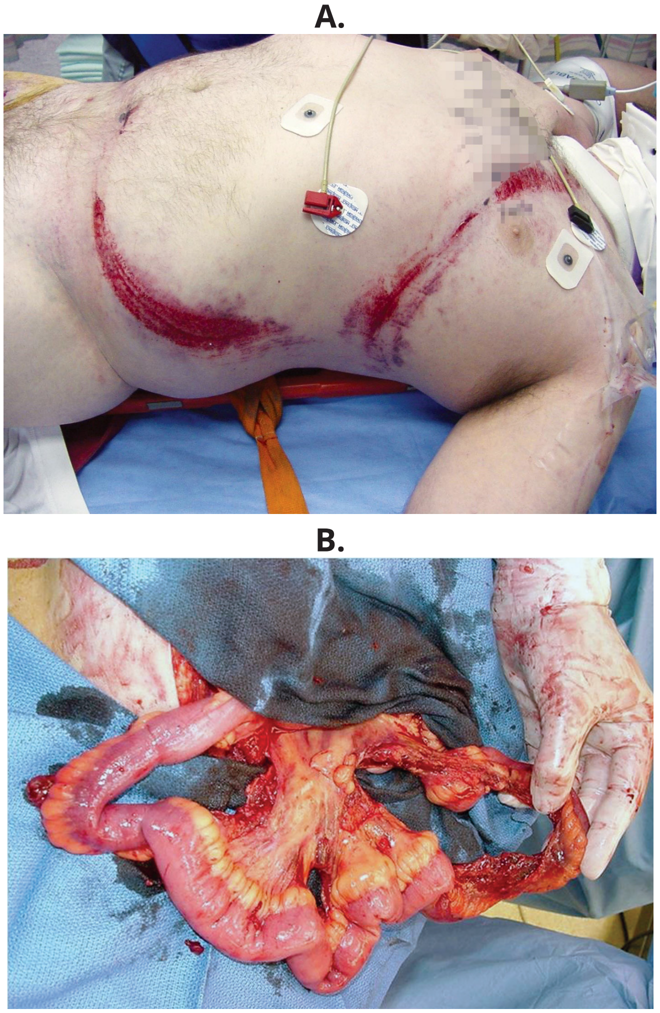
BLUNT MECHANISMS

A direct blow, such as contact with the lower rim of a steering wheel, bicycle or motorcycle handlebars, or an intruded door in a motor vehicle crash, can cause compression and crushing injuries to abdominopelvic viscera and pelvic bones. These forces deform solid and hollow organs and can cause rupture with secondary hemorrhage and contamination by visceral contents, leading to peritonitis.

Shearing injuries are a form of crush injury that is associated with mechanical restraint contusions. Patients injured in motor vehicle crashes or falls from significant heights may sustain deceleration injuries, in which there is a differential movement of fixed and mobile parts of the body. Examples include lacerations of the liver and spleen, two movable organs that are fixed at the sites of their supporting ligaments. Bucket-handle injury to the small bowel is another example of a deceleration injury. ■ **Figure 21-2** illustrates injuries associated with a mechanical restraint.


A.
Diaphragm
Liver
Stomach
Spleen
Thoraco-abdomen
Abdomen
B-C.
Abdominal aorta
Inferior vena cava
Flank
Kidneys
Anterior Abdomen
Ascending colon
Descending colon
Anterior axillary line
Posterior axillary lines
Duodenum
D.
Pelvic cavity
Bladder
Reproductive organs
Rectum

■ **Figure 21-1: Anatomy of the Abdomen. A.** Anterior abdomen and thoracoabdomen. **B.** Flank. **C.** Back. **D.** Pelvic cavity.



■ **Figure 21-2: Lap Belt and "Bucket Handle" Injuries. A.** Contusions consistent with mechanical restraints are associated with internal injuries. **B.** Small bowel "bucket handle" injury at operation.

In patients who sustain blunt trauma, the organs most frequently injured are the spleen (40% to 55%), liver (35% to 45%), and small bowel (5% to 10%). Additionally, there is a 15% incidence of retroperitoneal hematoma diagnosed during laparotomy for blunt trauma. Although restraint devices reduce the occurrence of many lethal injuries, these devices are associated with specific injury patterns. ■ **Table 21-1** lists injuries associated with restraint devices. Airbag deployment does not preclude abdominal injury.

PENETRATING MECHANISMS

Stab wounds and low-energy gunshot wounds cause tissue damage by lacerating and tearing. High-energy gunshot wounds transfer more kinetic energy, causing increased damage surrounding the track of the missile due to temporary cavitation. Stab wounds traverse adjacent abdominal structures and most commonly involve the liver (40%), small bowel (30%), diaphragm (20%), and colon (15%). Gunshot wounds can cause additional intra-abdominal injuries based on trajectory, cavitation effect, and fragmentation. Gunshot wounds most commonly injure the small bowel (50%), colon (40%), liver (30%), and abdominal

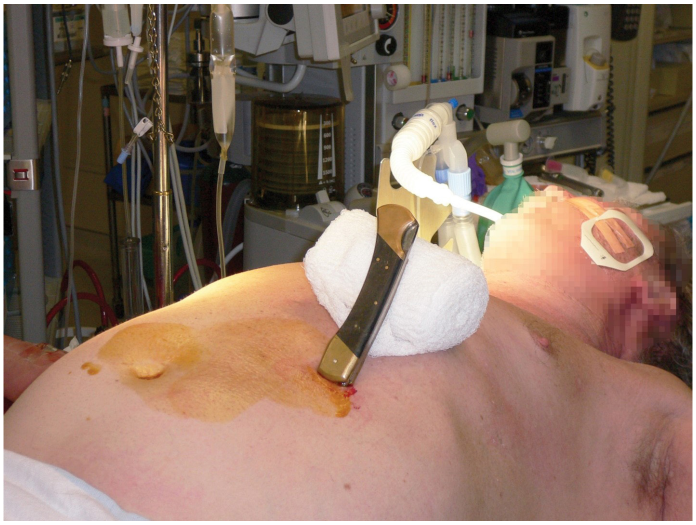
■ Table 21-1: Injuries Associated with Restraint Devices.

Injuries Associated with Restraint Devices		
Restraint Device	**Mechanism**	**Injuries**
Lap Seat Belt	• Compression • Hyperflexion	• Tear or avulsion of bowel mesentery (bucket handle) • Rupture of small bowel or colon • Thrombosis of iliac artery or abdominal aorta • Chance fracture of lumbar vertebrae • Pancreatic or duodenal injury
Shoulder Harness	• Sliding under the seat belt (“submarining”) • Compression	• Rupture of upper abdominal viscera • Intimal tear or thrombosis in innominate, carotid, subclavian, or vertebral arteries • Fracture or dislocation of cervical spine • Rib fractures • Pulmonary contusion
Air Bag	• Contact • Contact/ deceleration • Flexion (unrestrained) • Hyperextension (unrestrained)	• Face and eye abrasions • Cardiac injuries • Spine fractures

vascular structures (25%). The specific weapon, muzzle velocity, type of ammunition, and other ballistic factors (e.g., distance between a shotgun and the patient) are determinants of tissue injury. ■ **Figure 21-3** illustrates a stab wound to the abdomen.

BLAST MECHANISMS

Blast injury from explosive devices occurs through several mechanisms, including penetrating fragment wounds and blunt injuries from the patient being thrown or struck by projectiles. **The treating clinician considers the possibility of combined penetrating and blunt mechanisms in blast injury scenarios.** Patients close to the source of the explosion can incur additional injuries to the tympanic membranes, lungs, and bowel related to blast overpressure. These injuries may have delayed presentation. The potential for overpressure injury following an explosion should not distract the clinician from a systematic approach to identifying and treating blunt and penetrating injuries.



■ Figure 21-3: Stab Wound to the Abdomen. Stab wounds most commonly injure the liver, small bowel, diaphragm, and colon.

ASSESSMENT AND MANAGEMENT

In hypotensive patients, the goal is to rapidly identify all thoracic, abdominopelvic, and genitourinary injuries and determine whether one or more of these is the cause of hypotension. History, physical exam, and supplemental diagnostic tools can establish the presence of injuries and direct urgent hemorrhage control. In hemodynamically normal patients, a more detailed evaluation to determine the presence of injuries that can cause delayed morbidity and mortality is performed. This evaluation includes repeated physical examinations to identify signs of bleeding or peritonitis that may develop over time.

HISTORY

When assessing a patient injured in a motor vehicle crash, pertinent historical information includes the vehicle speed, type of collision (e.g., frontal impact, lateral impact, sideswipe, rear impact, or rollover), any intrusion into the passenger compartment, types of restraints, deployment of airbags, patient position in the vehicle, and status of other occupants.

For patients injured by falling, the height of the fall is important information due to the increased potential for deceleration injury at greater heights. Following explosion mechanisms, the proximity to the blast and if the blast occurred in a closed space are important details to understand the degree and likelihood of injuries. The patient, other vehicle occupants, witnesses, law enforcement, and emergency medical personnel may be able to provide historical information. Prehospital care providers may supply data regarding vital signs, visible injuries, and patient response to prehospital treatment. Important additional information to obtain from the patient includes the location and magnitude of pain.

PHYSICAL EXAMINATION

The physical examination of the torso is conducted in a systematic sequence: inspection, auscultation, percussion, and palpation. This is followed by examination of the pelvis and buttocks, as well as urethral, perineal, rectal, and vaginal exams (if indicated).

INSPECTION, AUSCULTATION, PERCUSSION, AND PALPATION

The patient is informed prior to performing each step of the examination. Clothing is removed, while protecting dignity, to allow for a thorough inspection. During the inspection, examine the anterior and posterior abdomen, as well as the lower chest and perineum, for abrasions and contusions from restraint devices, lacerations, penetrating wounds, impaled foreign bodies, evisceration of omentum or bowel, or a gravid abdomen.

Inspect the flank, scrotum, urethral meatus, and perianal area for blood, swelling, and bruising. Laceration of the perineum, vagina, rectum, or buttocks may be associated with an open pelvic fracture in blunt trauma patients. Skin folds in larger patients can mask penetrating injuries and increase the difficulty of assessing the abdomen and pelvis. For a complete back examination, perform a log roll. In conclusion of the physical exam, cover the patient with warmed blankets to prevent hypothermia.

Although auscultation is necessary (especially for determining presence of breath sounds), the presence or absence of bowel sounds does not necessarily correlate with injury, and the ability to hear bowel sounds may be compromised in a noisy emergency department or trauma bay. Percussion causes slight movement of the peritoneum and may elicit signs of peritoneal irritation. When rebound tenderness is present, do not seek additional evidence of irritation, as it will cause the patient unnecessary pain. Voluntary guarding by the patient may render the abdominal examination unreliable. In contrast, involuntary muscle guarding is a reliable sign of peritoneal irritation. Palpation may elicit and distinguish superficial (e.g., abdominal wall) and deep tenderness. Determine whether a gravid uterus is present, and if so, estimate the fundal height to roughly calculate gestational age.

PELVIC ASSESSMENT

Major pelvic hemorrhage can occur rapidly, and clinicians must make the diagnosis quickly to initiate appropriate resuscitative treatment. Unexplained hypotension may be the only initial indication of major pelvic disruption. Hypotension with a negative FAST and a pelvic fracture on anteroposterior (AP) x-ray is indicative of major pelvic hemorrhage. Utilizing adjuncts such as the FAST exam and an AP x-ray can be very helpful to diagnose pelvic trauma. Mechanical instability of the pelvic ring should be assumed in patients who have pelvic fractures with hypotension and no other source of blood loss. Placement of a pelvic binder is a priority and may be lifesaving in this circumstance.

Physical exam findings suggestive of pelvic fracture include evidence of disrupted urethra (scrotal hematoma or blood at the urethral meatus), discrepancy in limb length, and/or rotational deformity of a leg without visible fracture. In these patients, **avoid manually manipulating the pelvis, as doing so may dislodge an existing blood clot or cause further hemorrhage.** Gentle palpation of the bony pelvis for tenderness may provide useful information about the presence of a pelvic fracture. Avoid unnecessary manipulation.

The mechanically unstable hemipelvis migrates cephalad because of muscular forces and rotates outward secondary to the effect of gravity. External rotation of the unstable pelvis results in an increased pelvic volume that can accommodate a larger volume of blood. The pelvis can be compressed with a binder or sheet to decrease this potential space. The device is centered over the greater trochanters (not over the iliac crests). The presence of lower-extremity neurologic abnormalities or open wounds in the flank, perineum, vagina, or rectum may be evidence of pelvic-ring instability.

URETHRAL, PERINEAL, RECTAL, VAGINAL, AND GLUTEAL EXAMINATION

The patient is informed prior to performing a pelvic/perineal examination. The presence of blood at the urethral meatus strongly suggests a urethral injury. Ecchymosis or hematoma of the scrotum and perineum is also suggestive of urethral injury, although these signs may be absent immediately after injury. In patients who have sustained blunt trauma, the primary goals of the rectal examination are to assess sphincter tone and rectal mucosal integrity. Palpation of the prostate gland is not a reliable sign of urethral injury. **Do not place a urinary catheter in a patient with a perineal hematoma or blood at the urethral meatus before a definitive assessment for urethral injury.**

Bony fragments from a pelvic fracture wound can lacerate the vagina. A vaginal exam is indicated when injury is suspected, such as in the presence of complex perineal laceration or pelvic fracture. In unresponsive menstruating women, examination for the presence of tampons is important, as if left in place, delayed sepsis may occur.

ADJUNCTS TO PHYSICAL EXAMINATION

After assessment and management of external hemorrhage, the airway, breathing, and circulation, clinicians determine the indications for gastric tubes and urinary catheters as adjuncts to the primary survey.

GASTRIC TUBES

The therapeutic goal of a gastric tube placed early in the primary survey is relief of acute gastric dilation. Gastric tubes may reduce the incidence of aspiration in these cases. However, they can trigger vomiting in a patient with an active gag reflex. The presence of blood in the gastric contents may suggest an injury to the esophagus or upper-gastrointestinal tract if nasopharyngeal and oropharyngeal sources are excluded. If a patient has facial fractures or possible basilar skull fracture, insert the gastric tube through the mouth to prevent passage of the nasal tube through the cribriform plate into the brain. Gastric tubes are not indicated in every trauma scenario. They are inserted to clinically improve the patient or for diagnostic purposes.

URINARY CATHETERS

A urinary catheter placed during resuscitation will relieve retention, identify bleeding, and allow for monitoring of urinary output over time as an index of tissue perfusion. A distended bladder enhances pelvic imaging during FAST. Therefore, if FAST is being considered, delay placing a urinary catheter until after the test is completed. Gross hematuria is an indication of trauma to the genitourinary tract, including the kidneys, ureters, and bladder. The absence of hematuria does not exclude an injury to the genitourinary tract. A retrograde urethrogram (RUG) is mandatory when blood is seen at the urethral meatus. Other signs of urethral injury and indications from a RUG are inability to void, scrotal hematoma, and perineal ecchymosis. To reduce the risk of increasing the complexity of a urethral injury, confirm an intact urethra before inserting a urinary catheter. A disrupted urethra detected during the primary or secondary survey may be managed by insertion of a suprapubic tube by an experienced clinician.

DIAGNOSTIC STUDIES

With preparation and an organized team approach, the physical examination can be performed very quickly. Evaluation and management of thoracic hemorrhage is discussed in *Chapter 5, Breathing and Ventilation Assessment and Management*, and *Chapter 6, Circulation Assessment and Volume Resuscitation*. **In patients with hemodynamic abnormalities, rapid exclusion of intra-abdominal hemorrhage is necessary and can be accomplished with a FAST exam, or a diagnostic peritoneal lavage (DPL) if ultrasound is not available.**

A contraindication to further abdominopelvic diagnostic studies is an existing indication for emergent abdominal operation. Thoracic and abdominopelvic diagnostic studies are indicated in scenarios of altered sensorium, altered sensation, injury to adjacent structures (e.g., lower ribs, pelvis, and lumbar spine), unreliable physical examination, anticipated prolonged inability for clinical reassessment (e.g., general anesthesia, lengthy radiographic studies), abdominal or chest contusions consistent with mechanical restraints, and penetrating mechanism without immediate operative indication but with proximity to structures.

When intra-abdominal injury is considered, several studies can provide useful information. However, when indications for transfer exist, transfer is not delayed by performing time-consuming tests, including abdominal CT. **■ Table 21-2** summarizes the indications, advantages, and disadvantages of using DPL, FAST, and computed topography (CT) in evaluating blunt abdominal trauma.

■ Table 21-2: Comparison of DPL, FAST, and CT.

Comparison of DPL, FAST, and CT in Evaluation of Abdominal Trauma			
	DPL	**FAST**	**CT Scan**
Advantages	• Early operative determination • Performed rapidly • Can detect bowel injury • No need for transport from resuscitation area	• Early operative determination • Noninvasive • Performed rapidly • Repeatable • No need for transport from resuscitation area	• Anatomic diagnosis • Noninvasive • Repeatable • Visualizes retroperitoneal structures • Visualizes bony and soft-tissue structures • Visualizes extraluminal air
Disadvantages	• Invasive • Risk of procedure-related injury • Requires gastric and urinary decompression for prevention of complications • Not repeatable • Interferes with interpretation of subsequent CT or FAST • Low specificity • Can miss diaphragm injuries	• Operator-dependent • Bowel gas and subcutaneous air distort images • Can miss diaphragm, bowel, and pancreatic injuries • Does not completely assess retroperitoneal structures • Does not visualize extraluminal air • Body habitus can limit image clarity	• Higher cost and longer time • Radiation and IV-contrast exposure • Can miss diaphragm injuries • Can miss some bowel and pancreatic injuries • Requires transport from resuscitation area
Indications	• Abnormal hemodynamics in blunt abdominal trauma • Penetrating abdominal trauma without other indications for immediate laparotomy	• Abnormal hemodynamics in blunt abdominal trauma • Penetrating abdominal trauma without other indications for immediate laparotomy	• Normal hemodynamics in blunt or penetrating abdominal trauma • Penetrating back/flank trauma without other indications for immediate laparotomy

DPL, Diagnostic peritoneal lavage; FAST, focused assessment with sonography in trauma; CT, computed topography.

X-RAYS FOR ABDOMINAL TRAUMA

An AP chest x-ray is recommended for assessing patients with multisystem blunt trauma. An upright chest x-ray is useful to exclude a hemothorax or pneumothorax, or to determine the presence of intraperitoneal air. An AP pelvic x-ray may help to establish the source of blood loss in hemodynamically abnormal patients and in patients with pelvic pain or tenderness. A pelvic radiograph is not mandated for an alert, awake blunt trauma patient without pelvic pain or tenderness.

FOCUSED ASSESSMENT WITH SONOGRAPHY FOR TRAUMA

When performed by properly trained individuals, FAST is a rapid and reliable study for identifying intraperitoneal fluid. It has the advantage of being repeatable and can detect pericardial tamponade. FAST includes examination of four regions: the pericardial sac, hepatorenal fossa, splenorenal fossa, and pelvis or pouch of Douglas. Clinicians may perform a single or multiple repeat scans to detect progressive hemoperitoneum. FAST can be performed at the bedside in the resuscitation room simultaneously with other diagnostic or therapeutic procedures. ■ **Figure 21-4** illustrates FAST.

DIAGNOSTIC PERITONEAL LAVAGE

DPL is another rapidly performed study to identify hemorrhage. DPL may be performed in a hypotensive patient if ultrasound is not available to perform a FAST exam. As postprocedural pain can significantly alter subsequent examinations, generally the surgical team performs DPL. **Gastric and urinary decompression are performed prior to DPL for prevention of complications.** The technique is most useful in hemodynamically abnormal patients with blunt abdominal trauma or in penetrating trauma with multiple cavitary or apparent tangential trajectories. Where CT and/or FAST are available, DPL is rarely used because it is invasive, more time-consuming, and requires technical expertise. ■ **Figure 21-5** illustrates DPL.

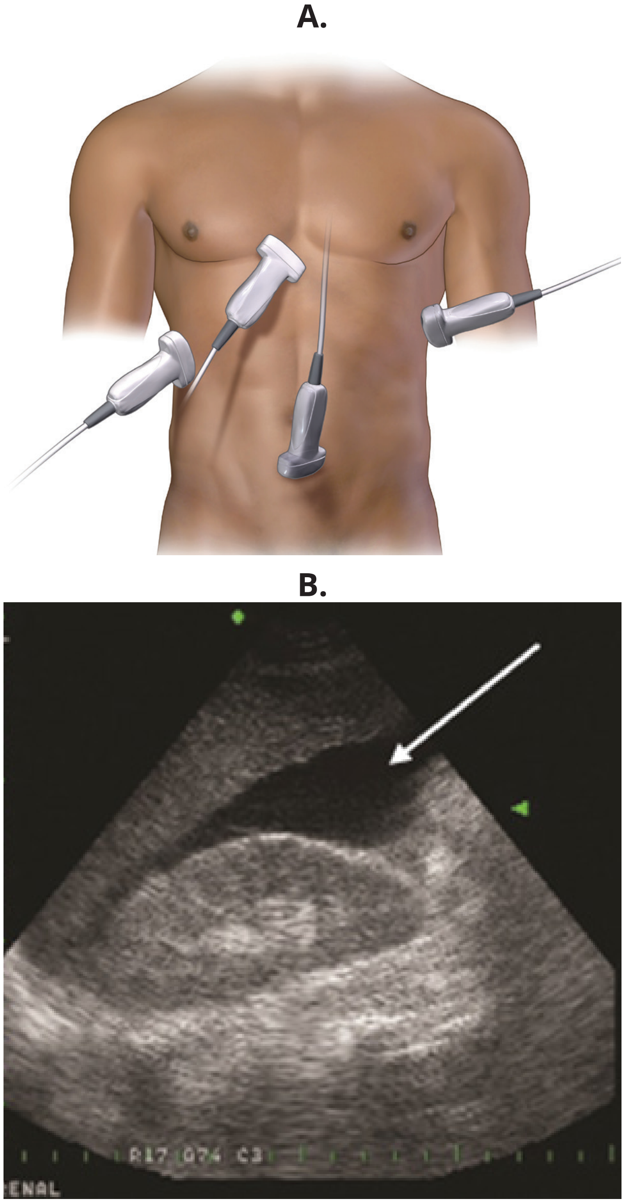
Relative contraindications to DPL include previous abdominal operations, morbid obesity, advanced cirrhosis, and preexisting coagulopathy. An open, semi-open, or closed (Seldinger) infraumbilical technique is acceptable in the hands of trained clinicians. In patients with pelvic fractures, an open supraumbilical approach is preferred to avoid entering an anterior preperitoneal pelvic hematoma. In patients with advanced pregnancy, an open supraumbilical approach is used to avoid damaging the enlarged uterus. DPL indications for laparotomy include aspiration of gastrointestinal contents or bile or aspiration of 10 cc or more of blood in hemodynamically abnormal patients.

COMPUTED TOMOGRAPHY

CT is a diagnostic procedure that requires transporting the patient to the device (i.e., removing the patient from the resuscitation area), administering IV contrast, and radiation exposure. **CT is a time-consuming procedure that is used in hemodynamically normal patients in whom there is no existing indication for an emergency laparotomy. CT scan is not performed if it delays transfer of a patient.**

CT scans can provide information identifying a specific organ injury as well as its extent. CT can diagnose retroperitoneal and pelvic injuries. Relative contraindications for using CT include a delay until the device is available, an uncooperative patient who cannot be safely sedated, and allergy to the contrast agent. CT may miss some gastrointestinal, diaphragmatic, and pancreatic injuries. In the absence of hepatic or splenic injuries (solid organ injury), the presence of free fluid in the abdominal cavity suggests an injury to the gastrointestinal tract and/or its mesentery. Many surgeons believe this finding to be an indication for early operative intervention.

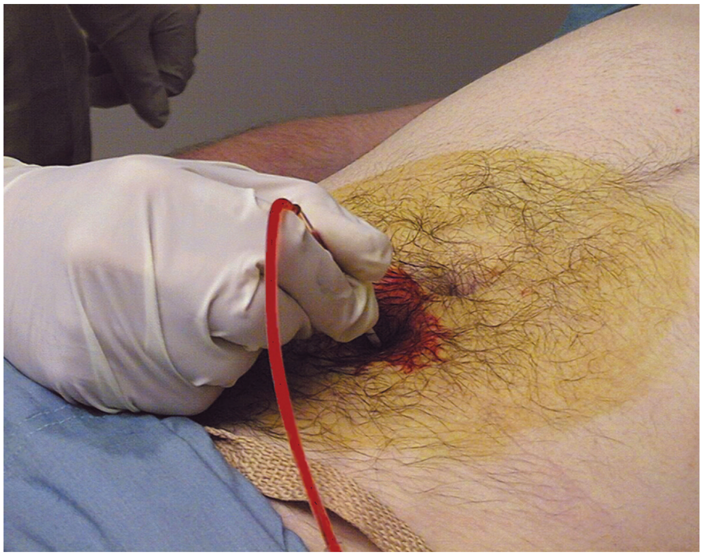
■ **Figure 21-4: Focused Assessment with Sonography for Trauma. A.** Probe locations. **B.** FAST image of the right upper quadrant showing the liver, kidney, and free fluid. Arrow points to free fluid which is hypoechoic, dark appearing, on FAST.



DIAGNOSTIC LAPAROSCOPY OR THORACOSCOPY

Diagnostic laparoscopy is an accepted method for evaluating a hemodynamically normal, blunt trauma patient without indication for laparotomy. Laparoscopy is useful to diagnose diaphragmatic injury and peritoneal penetration.

■ **Figure 21-5: Diagnostic Peritoneal Lavage (DPL).** DPL is a rapidly performed, invasive procedure that is sensitive for the detection of intraperitoneal hemorrhage.



CONTRAST STUDIES

Contrast studies can aid in the diagnosis of suspected injuries but should not delay the care of hemodynamically abnormal patients. These studies include urethrography, cystography, intravenous pyelogram, and gastrointestinal contrast studies.

Urethrography is performed before inserting a urinary catheter when a urethral injury is suspected. A urethrogram is performed with an 8 French urinary catheter secured in the meatus by balloon inflation to 1.5–2 mL. Approximately 30–35 mL of undiluted contrast material is instilled with gentle pressure. A radiograph is taken with an AP projection and with slight stretching of the penis toward one of the patient's shoulders. An adequate study shows reflux of contrast into the bladder.

A cystogram or CT cystography is the most effective method of diagnosing an intraperitoneal or extraperitoneal bladder rupture. A syringe barrel is attached to the indwelling bladder catheter and held 40 cm above the patient. Then 350 mL of water-soluble contrast is allowed to flow into the bladder until either the flow stops, the patient voids spontaneously, or the patient reports discomfort. An additional 50 mL of contrast is instilled to ensure bladder distention. Predrainage, filled, and postdrainage AP radiographs are obtained to definitively exclude bladder injury. CT evaluation of the bladder and pelvis (CT cystogram) is an alternative study that yields additional information about the kidneys and pelvic bones.

Suspected genitourinary injuries are best evaluated by contrast-enhanced CT scan. If CT is not available, intravenous pyelogram (IVP) provides an alternative. A high-dose, rapid injection of renal contrast ("screening IVP") is performed using 200 mg of iodine per kg body weight. Visualization of the renal calyces on an abdominal radiograph should appear 2 minutes after the injection is completed. Unilateral renal nonvisualization occurs with an absent kidney, thrombosis or avulsion of the renal artery, and massive parenchymal disruption. Nonvisualization may indicate further radiologic evaluation.

Isolated injuries to retroperitoneal gastrointestinal structures (e.g., duodenum, ascending or descending colon, rectum, biliary tract, and pancreas) may not immediately cause peritonitis and may not be detected on DPL or FAST. When injury to one of these structures is suspected, CT with contrast, specific upper- and lower-gastrointestinal intravenous contrast studies, and/or pancreaticobiliary imaging studies can be useful. The surgeon who ultimately may operate should guide these studies.

EVALUATION OF SPECIFIC PENETRATING INJURIES

The etiology of injury (e.g., stab wound or gunshot), anatomical location (e.g., thoracoabdominal, anterior, posterior, or flank), and available resources influence the evaluation of penetrating abdominal trauma. In anterior abdominal stab wounds, options include serial physical examination, FAST, DPL, and CT. Diagnostic laparoscopy is a reliable study to determine peritoneal and diaphragmatic penetration in thoracoabdominal injuries, as are contrast CT scans. In all cases of penetrating trauma, immediate surgery may be required for diagnosis and treatment.

Most abdominal gunshot wounds are managed by exploratory laparotomy. The incidence of significant intraperitoneal injury approaches 98% when peritoneal penetration is present. Stab wounds to the abdomen may be managed more selectively, but approximately 30% cause intraperitoneal injury. Thus, indications for laparotomy in patients with penetrating abdominal wounds include hemodynamic abnormality, gunshot wound with a transperitoneal trajectory, signs of peritoneal irritation, and signs of peritoneal penetration (e.g., evisceration).

THORACOABDOMINAL WOUNDS

Evaluation options for patients without indications for immediate laparotomy or thoracotomy, but with possible injuries to the diaphragm and upper abdominal structures, include thoracoscopy, laparoscopy, DPL, and CT.

ANTERIOR ABDOMINAL WOUNDS: NONOPERATIVE MANAGEMENT

Approximately 55% to 60% of all patients with stab wounds that penetrate the anterior peritoneum have hypotension, peritonitis, or evisceration of the omentum or small bowel. Emergency laparotomy is indicated in these scenarios. However, nonoperative management may be considered in hemodynamically normal patients without peritoneal signs or evisceration. Less-invasive diagnostic options for these patients (who may have pain at the site of the stab wound) include serial physical examinations over a 24-hour period (with or without serial FAST exams), DPL, CT scan, or diagnostic laparoscopy.

Although a positive FAST may be helpful, a negative FAST does not exclude the possibility of a visceral injury without a large volume of intra-abdominal fluid. Serial physical examinations are labor intensive but have an overall accuracy rate of 94%. CT scan and DPL may allow for earlier diagnosis of injury in relatively asymptomatic patients. Diagnostic laparoscopy can confirm or exclude peritoneal penetration, but it is less useful in identifying specific injuries. The surgeon determines when DPL and laparoscopy are to be used.

FLANK AND BACK INJURIES: NONOPERATIVE MANAGEMENT

The thickness of the flank and back muscles protects underlying viscera against injury from many stab wounds and some gunshot wounds. For those who do not have indications for immediate laparotomy, less-invasive diagnostic options include serial physical examinations (with or without serial FAST exams), contrast CT scans, and DPL. Rarely, retroperitoneal injuries can be missed by serial examinations and contrast CT. Early outpatient follow-up is mandatory after the 24-hour period of inhospital observation because of the subtle presentation of certain colonic injuries. DPL can be used as an early screening test. A positive DPL is an indication for an urgent laparotomy. However, DPL may not detect retroperitoneal colon injuries.

INDICATIONS FOR LAPAROTOMY FOLLOWING BLUNT TRAUMA

Surgical judgment is required to determine the timing and need for laparotomy. The following indications are commonly used:

- Hypotension with a positive FAST, clinical evidence of intraperitoneal bleeding, or without another source of bleeding
- Evisceration
- Peritonitis
- Free air, retroperitoneal air, or rupture of the hemidiaphragm
- Contrast-enhanced CT that demonstrates ruptured gastrointestinal tract, genitourinary injury, or severe visceral parenchymal injury
- DPL aspiration of gastrointestinal contents or bile
- DPL aspiration of 10 cc or more of blood in hemodynamically abnormal patients

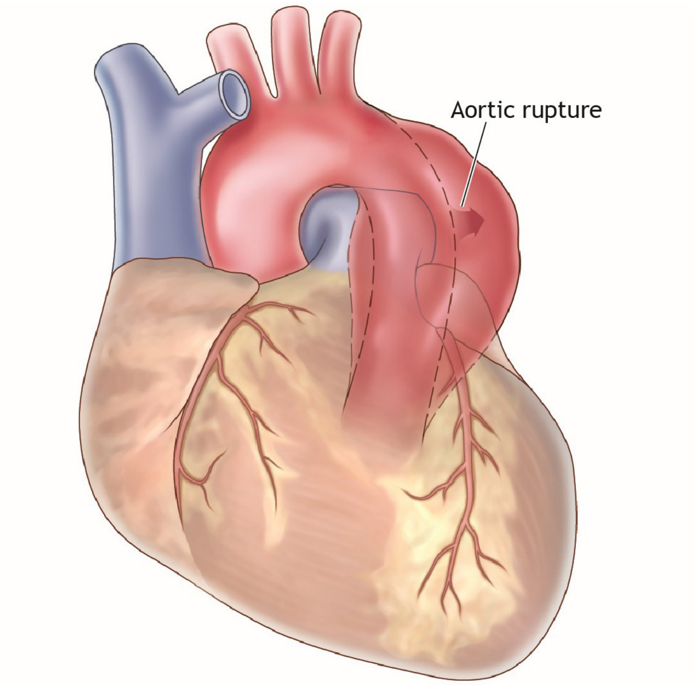
EVALUATION OF OTHER SPECIFIC INJURIES

The liver, spleen, and kidney are the organs predominantly involved following blunt trauma, although the relative incidence of hollow visceral perforation and lumbar spinal injuries increases with nonoptimal mechanical restraint usage. Diagnosis of injuries to the aorta, esophagus, diaphragm, duodenum, pancreas, genitourinary system, and small bowel can be difficult.

BLUNT AORTIC INJURY

Blunt aortic injury (BAI) is commonly associated with motor vehicle crashes, including those involving motorcycles. Other mechanisms include pedestrians struck by vehicles, falls, and crush injuries. Autopsy studies show that over 60% of BAI occurs at the ligament arteriosum, where the relatively fixed descending aorta meets the more mobile aortic arch. History of a rapid-deceleration mechanism alerts the clinician to the potential of a BAI. BAI can be rapidly lethal. Without treatment, 20% of patients who arrive to the hospital will die within 30 hours. ■ **Figure 21-6** illustrates BAI.

■ **Figure 21-6: Blunt Aortic Injury.** Blunt aortic injury is a common cause of sudden death after a vehicle collision or fall from height. A history of decelerating force prompts investigation which is performed following completion of initial assessment (primary and secondary surveys) and restoration of normal hemodynamic and respiratory function.

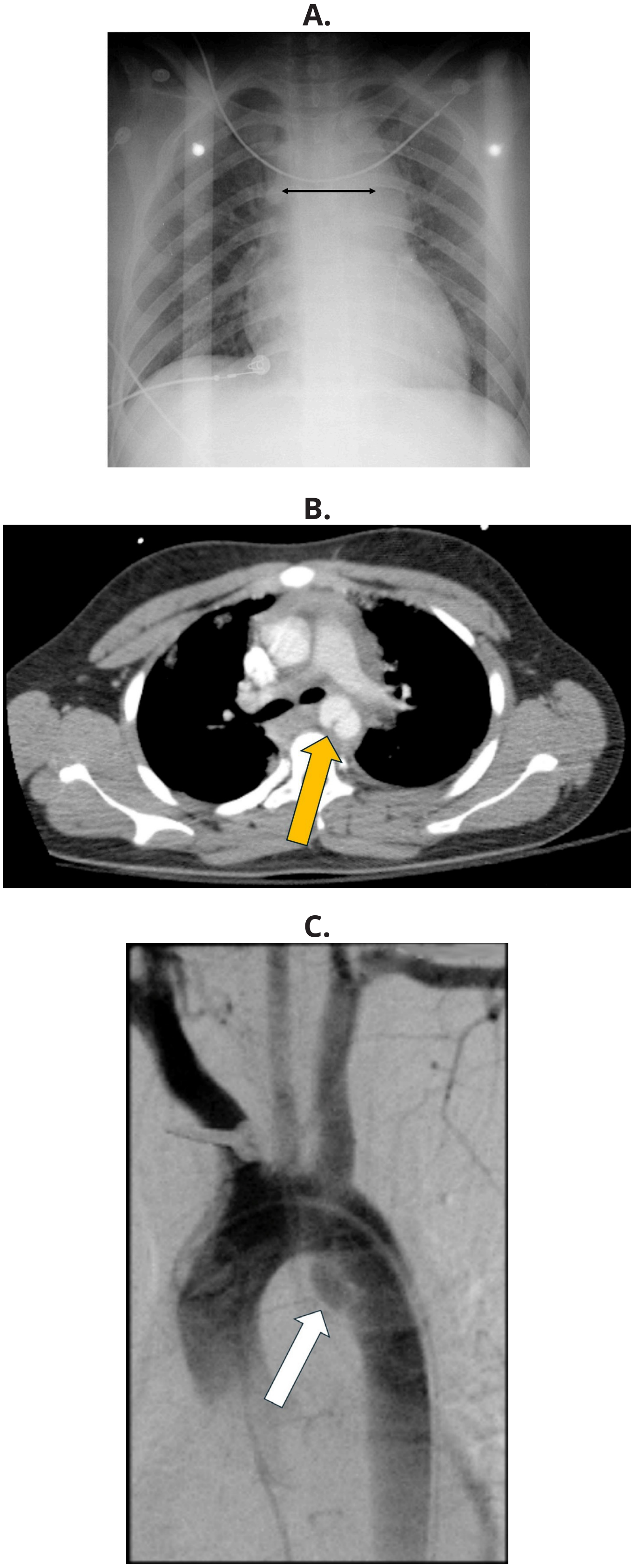


Several signs of BAI may be present on chest radiograph. ■ **Table 21-3** lists chest x-ray (CXR) signs associated with BAI. However, **a normal chest radiograph does not exclude BAI.** A CT angiogram (CTA) is currently the best study to diagnose and exclude BAI. Reported sensitivities of CT angiogram range from 95% to 100%, with negative predictive values ranging from 99% to 100%. If CT angiogram is equivocal, transesophageal echocardiography, intravascular ultrasound, and angiography can be used, although these are rarely employed. ■ **Figure 21-7** illustrates imaging of BAI.

■ **Table 21-3: CXR Signs of BAI.**

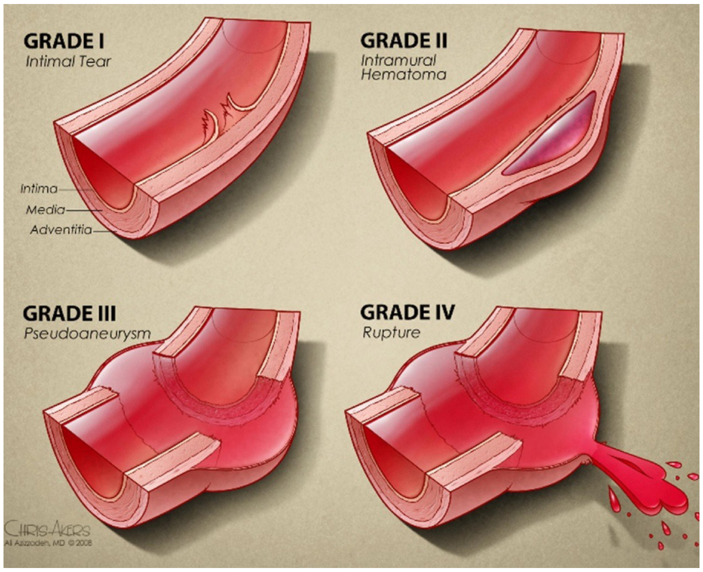
Chest Radiograph Signs Associated with Aortic Injury
• Wide mediastinum (supine chest radiograph >8 cm; upright >6 cm)
• Obscured, indistinct, or enlarged aortic knob; abnormal aortic arch contour
• Left “apical cap” (opacity at apex of left lung representing extrapleural blood)
• Large left hemothorax
• Displacement of the left mainstem bronchus
• Deviation of nasogastric tube to the right
• Deviation of trachea to the right and/or right mainstem bronchus inferiorly
• Wide left paravertebral stripe

■ Figure 21-7: Blunt Aortic Injury A. Chest radiograph illustrating a widened mediastinum. Arrow illustrates mediastinal width. **B.** CT scan illustrating blunt aortic injury. Arrow indicates site of injury. **C.** Angiogram illustrating blunt aortic injury. Arrow indicates site of injury.



Management of BAI can be divided into medical and surgical therapy based on injury grade. Initial and often definitive treatment of Grade I and many Grade II injuries is blood pressure control. Data suggest that maintaining systolic blood pressure below 100 mm Hg and pulse rate below 100 beats per minute decreases the risk of rupture. The initial medication of choice is a titratable short-acting beta blocker such as esmolol. **■ Figure 21-8** illustrates grades of BAI.

■ Figure 21-8: Grades of BAI.



Surgical management depends on hemodynamic status and the overall burden of injury. Currently, repair is recommended for all Grade III and IV injuries. Severe hypotension is usually from a source other than the BAI, as free aortic rupture is nearly always fatal before control can be achieved. If BAI is identified and the facility does not have resources to manage the patient, transfer is initiated as soon as possible.

DIAPHRAGM INJURIES

Blunt tears can occur in any portion of either hemidiaphragm, although the left hemidiaphragm is most often injured. The right hemidiaphragm is protected by the liver. Many injuries on the right are not repaired operatively. A common blunt force injury is 5–10 cm in length and involves the posterolateral left hemidiaphragm. Abnormalities on the initial chest x-ray include elevation or "blurring" of the hemidiaphragm, a hemothorax, an abnormal gas shadow that obscures the hemidiaphragm, or a gastric tube positioned in the chest (see *Chapter 5, Breathing and Ventilation Assessment and Management*). However, the initial chest x-ray can be normal. Additional discussion of diaphragm injuries is located in *Chapter 5, Breathing and Ventilation Assessment and Management.*

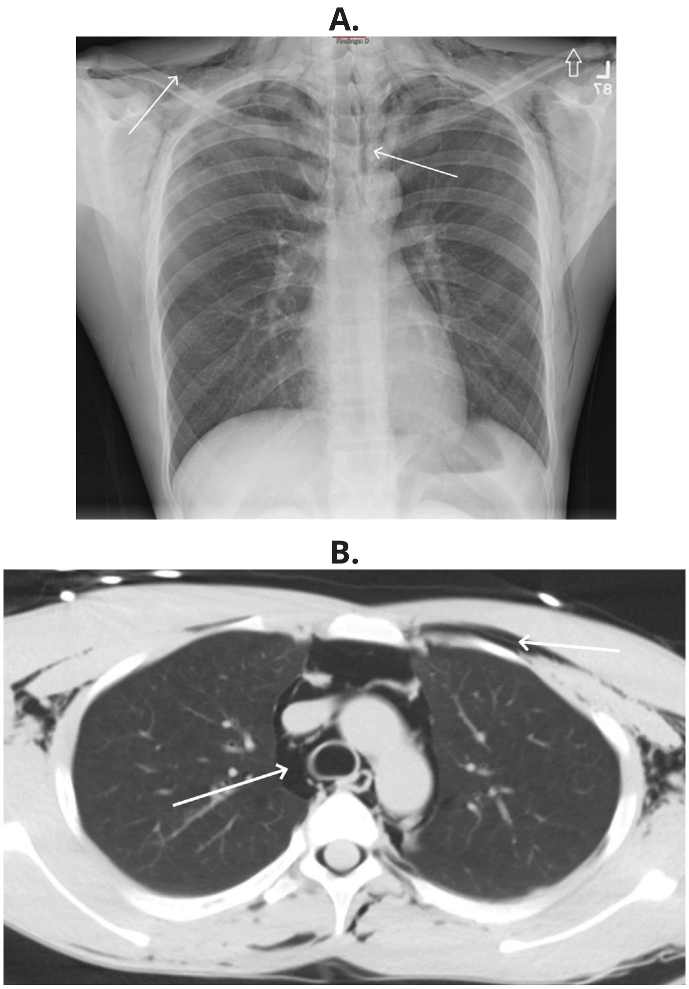
PNEUMOMEDIASTINUM

Pneumomediastinum (air within the mediastinal structures) can occur after thoracic, neck, or abdominal trauma. Air in the tissue may originate from the tracheobronchial tree, a pneumothorax, or the esophagus. Major tracheobronchial or esophageal injuries after blunt trauma are rare. Most commonly, mediastinal air originates from lung parenchyma. Traumatic rupture of alveoli due to transient increased intrathoracic pressure causes air to dissect into peribronchial sheaths and travel medially. A laceration of the mediastinal pleura can allow direct communication between a pneumothorax and the mediastinum.

Most cases of traumatic pneumomediastinum have associated injuries such as lung contusions, pulmonary lacerations, or rib fractures. Pneumomediastinum can be suspected based on the presence of subcutaneous emphysema at the base of the neck or auscultation of a "chomping" sound synchronous with the cardiac cycle (Hamman's sign). Dyspnea, voice changes, and chest pain may be present, but these findings lack specificity.

Pneumomediastinum can be seen on chest x-ray obtained during the primary survey. CT scan is more sensitive for diagnosis. Following penetrating injuries, particularly transmediastinal gunshot wounds, further investigation with CT scan is performed after restoration of adequate hemodynamics. If the source cannot be adequately identified, or if specific injuries are suspected, further evaluation may include a water-soluble contrast swallow study, esophagoscopy, and/or bronchoscopy. Trauma-related pneumomediastinum is managed based on the inciting etiology. ■ **Figure 21-9** illustrates pneumomediastinum.

■ **Figure 21-9: Pneumomediastinum.** **A.** Chest radiograph and **B.** CT Scan illustrating pneumomediastinum with subcutaneous emphysema. Arrows point to air in the tissues.



ESOPHAGEAL INJURIES

The majority of esophageal injuries are due to penetrating trauma. Occasionally, bone fragments from a spine fracture can directly lacerate the esophagus. A rapid increase in pressure within the esophageal lumen can lead to perforation. This rise in pressure can be the result of direct force to the stomach, the result of blast injuries, or the result of aggressive bag-mask ventilation, particularly in toddlers and infants.

The presentation of esophageal injuries can be subtle or overt. Retrosternal pain is common in awake patients, but this is also common with other thoracic injuries. Esophageal injury is suspected following transmediastinal gunshot wounds or gunshot wounds associated with vertebral body fractures. Occasionally, tissue necrosis caused by high-speed projectile cavitation can result in a delayed perforation. Esophageal injuries may be clinically occult until mediastinitis and septic shock develop.

Patients presenting with life-threatening hemorrhage are treated with emergent operation. Exploration will diagnose the esophageal injury if present. For patients with adequate hemodynamic status, CT scan and esophagoscopy are the most sensitive studies. CT scan may reveal periesophageal gas and fluid, mediastinal air/fluid collections, or communication of air between the esophagus and the mediastinum. Up to 20% of esophageal injuries may be initially missed by a fluoroscopic, non-CT, contrast study. Upper endoscopy is performed with low air inflation and delicately to reduce the risk of enlarging a perforation or converting the injury from a contained to an uncontained situation.

If operative repair is chosen, earlier management results in better outcomes. In facilities with the equipment and expertise, an esophageal stent may be selected. If the patient is unable to tolerate operative intervention, bedside drainage may be performed. As management of esophageal injury is complex, early transfer to higher-level care is appropriate.

DUODENAL INJURIES

Duodenal rupture is classically encountered in unrestrained drivers involved in frontal-impact motor vehicle collisions and patients who sustain direct blows to the abdomen, such as from bicycle handlebars. A bloody gastric aspirate or retroperitoneal air on an abdominal radiograph or CT raises suspicion for this injury. An upper-gastrointestinal x-ray series, double-contrast CT, or emergent laparotomy is indicated for high-risk patients.

PANCREATIC INJURIES

Pancreatic injuries often result from a direct epigastric blow that compresses the pancreas against the vertebral column. An early normal serum amylase level does not exclude major pancreatic trauma. Conversely, the amylase level can be elevated from nonpancreatic sources. Contrast CT may not identify significant pancreatic trauma in the immediate postinjury period (up to 8 hours). CT may be repeated, or other pancreatic imaging performed, if injury is suspected. Surgical exploration of the pancreas may be warranted following equivocal diagnostic studies.

GENITOURINARY INJURIES

Contusions, hematomas, and ecchymoses of the back or flank are markers of potential underlying renal injury, and evaluation (CT or IVP) of the urinary tract is indicated. Gross hematuria is an indication for imaging the urinary tract. An abdominal CT scan with IV contrast can document the presence and extent of a blunt renal injury, which frequently can be treated nonoperatively. Thrombosis of the renal artery and disruption of the renal pedicle secondary to deceleration are injuries in which hematuria may be absent. With either injury, an IVP, CT, or renal arteriogram can be useful in diagnosis. These imaging studies are also useful in diagnosing ureteral injuries. Ureteral injuries are considered in all penetrating trauma patients with microscopic or gross hematuria and can be diagnosed with a contrast CT specifically timed to identify ureteral injury. Urology consultation is appropriate for injury to the urinary tract. Urethral injuries have been addressed previously (see Urinary Catheters under Adjuncts to Physical Examination, above).

HOLLOW VISCUS INJURIES

Blunt injury to the intestines generally results from sudden deceleration with subsequent shearing near a fixed point of attachment, particularly if the seat belt was positioned incorrectly. A transverse, linear ecchymosis on the abdominal wall (seat-belt sign) or lumbar distraction fracture (e.g., Chance fracture) on x-ray are associated with intestinal injury. Although some patients have early abdominal pain and tenderness, the diagnosis of hollow viscus injuries can be difficult as they are not always associated with hemorrhage. Additionally, the superficial soft-tissue injury may be extremely tender to palpation, thus complicating the assessment for peritonitis.

SOLID ORGAN INJURIES

Injuries to the liver, spleen, and kidney that result in shock, hemodynamic abnormality, or evidence of continuing hemorrhage are indications for urgent laparotomy. Solid organ injury in hemodynamically normal patients can often be managed nonoperatively. Hospital admission is performed for frequent observation. Evaluation by a surgeon is important. Concomitant hollow viscus injury occurs in less than 5% of patients initially diagnosed with isolated solid organ injuries.

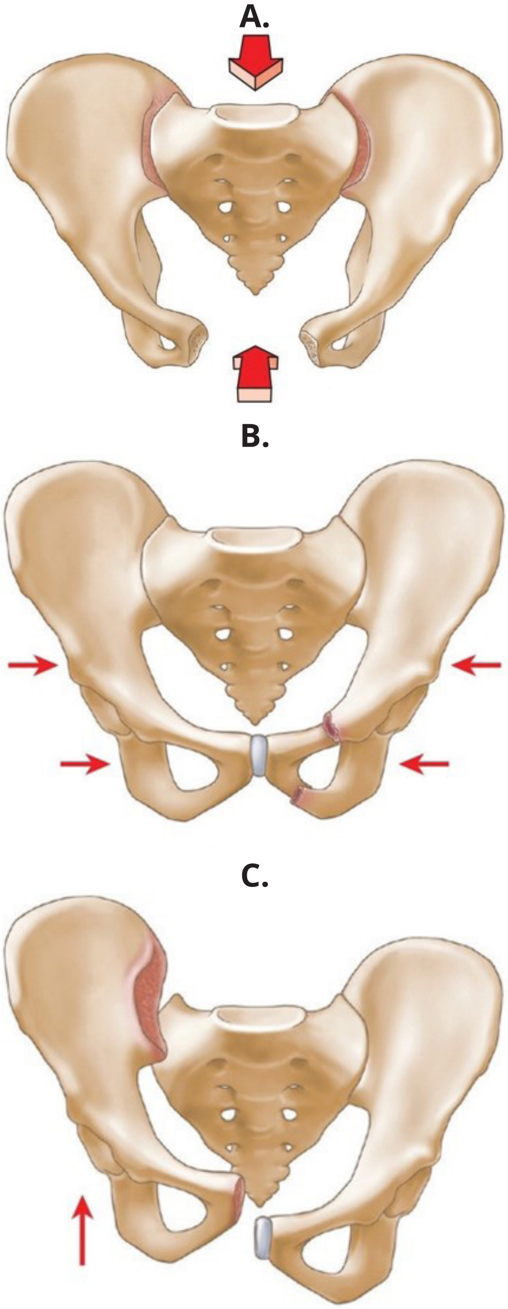
PELVIC FRACTURES AND ASSOCIATED INJURIES

Patients with hypotension and pelvic fractures have high mortality. Rigorous decision-making is crucial for optimal outcomes. Pelvic fractures associated with hemorrhage commonly involve disruption of the posterior osseous ligamentous complex (i.e., sacroiliac, sacrospinous, sacrotuberous, and fibromuscular pelvic floor) as evidenced by a sacral fracture, a sacroiliac fracture, and/or dislocation of the sacroiliac joint.

MECHANISM OF INJURY AND CLASSIFICATION

Blunt pelvic-ring injury can occur following a motor vehicle crash, motorcycle crash, pedestrian–vehicle collision, direct crushing injury, or fall. Pelvic fractures may be simply classified into four types based on injury force patterns: AP compression, lateral compression, vertical shear, and combined mechanism. Further information and subclassifications are described in *Chapter 10, Musculoskeletal Trauma.* ■ **Figure 21-10** illustrates types of pelvic fractures.

■ **Figure 21-10: Pelvic Fractures. A.** Anteroposterior (AP) Compression fracture. **B.** Lateral compression fracture. **C.** Vertical shear fracture.



AP compression injury is often associated with a motorcycle or head-on motor vehicle crash. This mechanism produces external rotation of the hemipelvis with separation of the symphysis pubis and tearing of the posterior ligamentous complex. The disrupted pelvic ring widens, tearing the posterior venous plexus and branches of the internal iliac arterial system. Hemorrhage can be severe and life-threatening.

Lateral compression injury, which involves force directed laterally into the pelvis, is the most common mechanism of pelvic fracture in a motor vehicle collision. In contrast to AP compression, the hemipelvis rotates internally during lateral compression, reducing pelvic volume and reducing tension on the pelvic vascular structures. This internal rotation may drive the pubis into the lower genitourinary system, potentially causing injury to the bladder and/or urethra. Hemorrhage and other sequelae from lateral compression injury may produce severe and sometimes permanent morbidity. Elderly patients may develop significant bleeding from pelvic fractures from this mechanism. Early hemorrhage control techniques such as angioembolization may be indicated. Frail and elderly patients may bleed significantly following lower-force trauma due to resulting lateral compression fractures.

Vertical displacement (vertical shear) of the sacroiliac joint disrupts the iliac vasculature and causes severe hemorrhage. In this mechanism, a high-energy shear force occurs along a vertical plane across the anterior and posterior aspects of the pelvic ring, typically as the result of a fall from a height. This vertical shearing disrupts the sacrospinous and sacrotuberous ligaments, leading to significant pelvic instability.

MANAGEMENT

Hemorrhage is the major potentially reversible factor contributing to mortality following pelvic fracture. Initial management of hypovolemic shock associated with a major pelvic disruption requires rapid hemorrhage control and fluid, preferably blood, resuscitation. Hemorrhage control is achieved through mechanical stabilization of the pelvic ring and external counterpressure. Patients with these injuries may be initially assessed and treated in facilities that do not have the resources to definitively manage the associated hemorrhage. By applying a support directly to the pelvis, clinicians can splint the disrupted pelvis and further reduce the potential space for hemorrhage. Because pelvic injuries associated with major hemorrhage externally rotate the hemipelvis, internal rotation of the lower limbs may assist in hemorrhage control by reducing pelvic volume.

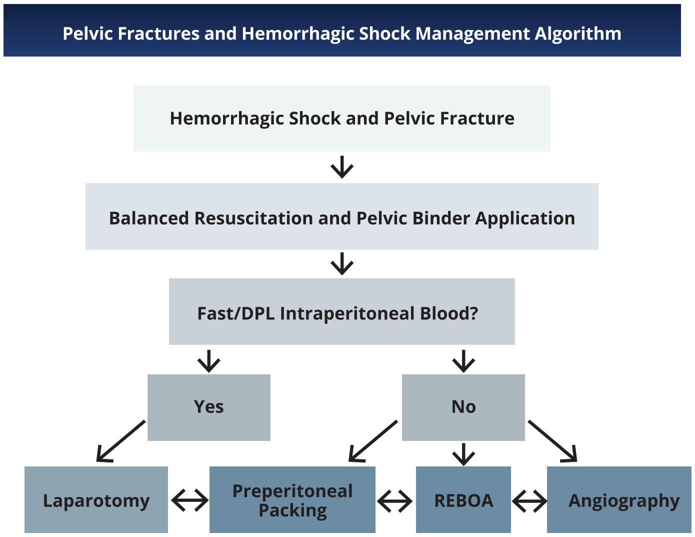
A sheet, commercial pelvic binder, or other device can produce sufficient temporary fixation for the injured pelvis when applied at the level of the greater trochanters of the femur (see *Chapter 6, Circulation Assessment and Volume Resuscitation*). Pelvic compression/support devices are a temporary emergency procedure. Proper application and vigilant monitoring are crucial. Tight devices or those left in position for prolonged time periods can cause skin breakdown and ulceration over bony prominences.

Optimal care of patients with hemodynamic abnormalities related to pelvic fracture involves a team effort of traumatologists, orthopaedic specialists, and interventional radiologists or vascular surgeons. Angiographic embolization is frequently employed to stop arterial hemorrhage related to pelvic fractures. Preperitoneal packing is another method to control pelvic hemorrhage, either as an initial procedure or when angioembolization is delayed or unavailable. Hemorrhage control techniques are not exclusive, and more than one technique may be applied to achieve hemorrhage control. An experienced traumatologist should direct the therapeutic plan based on available resources.

Some centers employ resuscitative endovascular balloon occlusion of the aorta (REBOA) to manage pelvic fractures causing hemorrhagic shock. REBOA stops or slows blood flow within the aorta and thus to targeted zones of injury. While the REBOA balloon is deployed, resuscitation is continued and immediate definitive intervention pursued. Currently, REBOA is not a tool for stabilization prior to transfer to another facility and is not placed unless definitive surgical care and hemostasis are available at the same institution. **■ Figure 21-11** illustrates a flowchart for management of hemorrhagic shock in patients with pelvic fractures.

Significant resources are required to care for patients with severe pelvic fractures. Early consideration of transfer to an advanced care institution (e.g., trauma center) is essential for optimal results. For hemodynamically abnormal patients with pelvic fractures or hemodynamically normal patients with significant solid organ injury in resource-limited environments, the absence of surgical and/or angiographic resources are indications for early transfer to a center with these capabilities.

■ Figure 21-11: Flowchart for Pelvic Fractures and Hemorrhagic Shock Management.


Pelvic Fractures and Hemorrhagic Shock Management Algorithm
Hemorrhagic Shock and Pelvic Fracture
Balanced Resuscitation and Pelvic Binder Application
Fast/DPL Intraperitoneal Blood?
Yes
No
Laparotomy
Preperitoneal Packing
REBOA
Angiography

CHAPTER SUMMARY

During Initial Assessment xABCDEs, hemodynamically abnormal patients with multiple blunt injuries should be rapidly evaluated for truncal bleeding or contamination from the gastrointestinal tract by performing FAST or DPL.

The decision to transfer to a higher level of care is made early. Patients are resuscitated without performing nonessential diagnostic tests.

Indications for CT scan in hemodynamically normal patients include inability to reliably evaluate the abdomen with physical examination and potential thoracic and/or abdominopelvic injury as reflected by mechanism, examination, and/or adjunct results.

Early surgical consultation is recommended for evaluation and management of potential thoracic, abdominopelvic, and genitourinary injuries.

KEY LEARNING POINTS

- **Early evaluation for torso hemorrhage is performed during the Circulation portion of the primary survey.**
- **Shearing and crush injuries may occur in association with mechanical restraints.**
- **Hemorrhage is the major potentially reversible factor contributing to mortality following pelvic fracture.**
- **Avoid manual displacement of pelvic fractures due to the risk of aggravating hemorrhage.**
- **Do not place a urinary catheter if a urethral injury is potentially present.**
- **In patients with hemodynamic abnormalities, rapid exclusion of intra-abdominal hemorrhage can be accomplished with a FAST exam or a DPL.**
- **CT is used in hemodynamically normal patients in whom there is no existing indication for an emergency laparotomy. CT scan is not performed if it delays transfer of a patient.**
- **BAI may occur following MVCs, falls, and other rapid deceleration mechanisms. A normal chest radiograph does not exclude BAI.**

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22

Penetrating Trauma

Courtesy of John H. Armstrong, MD, FACS

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Describe techniques to control external hemorrhage
2. Determine which patients require surgical consultation
3. Identify the imaging options for patients with penetrating torso trauma
4. Explain the significance of odd or even number of bullet wounds on examination
5. Describe indications for ordering massive transfusion protocol
6. Explain the significance of a thorough skin examination in patients with penetrating trauma

22

Penetrating Trauma

CHAPTER STATEMENT

An organized approach to the evaluation and management of patients with penetrating injury is based on regional anatomy and patient physiology. Minimizing delays in the recognition of injuries can lead to decreased morbidity and mortality.

INTRODUCTION

Penetrating injuries can be unintentional or the result of interpersonal violence, armed conflicts, or self-harm. Objects that pierce the skin can extend to deeper body areas and damage soft tissue, blood vessels, nerves, bones, and organs. Injury results from the abrupt application of a force over a focal area. The capacity of an implement to cause injury relates to its kinetic energy. Tissues have varying capacity to absorb energy and can therefore be more or less resistant to injury.

There are an estimated 4.4 million injury-related deaths annually worldwide. Unintentional injuries account for 3.15 million of those deaths, and violence-related injuries take 1.25 million lives each year. 1 in 10 of all injury-related deaths are from homicide, 1 in 6 from suicide, and 1 in 61 from war and conflict. In some areas of the world these injuries occur quite commonly and in other regions may be exceedingly rare. Some populations are more vulnerable to penetrating injury than others because of where they are born, grow, work, and live. Young men living in poverty are at particularly high risk of penetrating trauma injury.

PATHOPHYSIOLOGY

Penetrating trauma results from an object piercing the skin and potentially damaging soft tissue, blood vessels, nerves, bones, or organs. Tissues have varying capacity to absorb energy and can therefore be more or less resistant to injury. Skin, muscle, intestines, and blood vessels are more resistant because of their ability to stretch, while organs like the liver, spleen, kidney, and brain have less tensile strength and will split, shatter, or tear more easily. Injury results from the abrupt application of a force over a focal area. Any object with enough kinetic energy can penetrate the skin. The greater the kinetic energy of an object, the more damage is inflicted to tissues and, generally, the deeper it will pass.

The physiologic response to penetrating injury is directly related to the area of injury. The central torso and the central nervous systems are areas of particular vulnerability. Blood loss can be catastrophic when one considers that an average 80-kilogram person has a total blood volume of 4,800 milliliters. Cardiac output is, on average, 5.5 liters of blood per minute and can reach 11 liters during times of stress. An injury to the ascending aorta could result in loss of 20% of the blood volume in only 4.6 seconds.

As the body compensates for loss of circulating blood volume, vasoconstriction occurs. Catecholamines are released, and the renin-angiotensin-aldosterone system is activated. Vasoconstriction can limit bleeding from the area of injury but also decreases perfusion to organs. To maintain cardiac output when stroke volume is decreased, heart rate increases. Endorphin release can dull the perception pain. When these patients arrive to a trauma bay, these protective responses can maintaining their tenuous hemodynamics. Providing sedatives and analgesics to assist with rapid-sequence intubation has the potential to produce catastrophic decompensation without hemorrhage control and resuscitation.

INJURY MECHANISM

Knives and bullets are the objects that are commonly thought of as causes of penetrating trauma. However, bone fragments, metal fragments, shrapnel from explosions (secondary blast injury), nails, pellets, arrows, and pieces of glass should not be forgotten as potential implements of penetrating injury. ■ **Box 22-1** lists common penetrating wounding implements.

■ Box 22-1: Weapons Associated with Penetrating Trauma.

Handguns	Pistols Revolvers
Long guns	Rifles Shotguns Machine Guns
Air guns	Pneumatic with carbon dioxide cartridges
Cross bows and bows	
Hand-driven implements	Knives Swords Needles Ice picks
Explosive fragments	

Bullets can break into smaller projectiles or fracture bone that then can become a secondary projectile and produce more tissue injury. Objects can pass through or perforate, resulting in two wounds without a residual foreign body. Objects can also penetrate and remain in the body, often a distance away from where they entered. Piercing objects can either remain in situ, as with impalement, or enter and exit through the same path.

ASSESSMENT

Principles of evaluation and management follow the same general guidelines as nonpenetrating injury. Some nuances exist and should be noted.

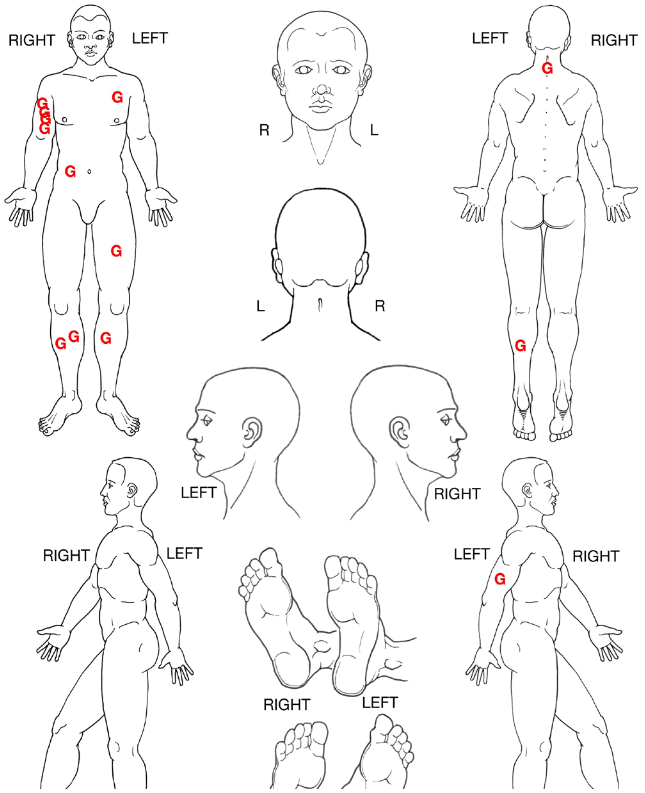
Penetrating wounds may be associated with active external hemorrhage or may have resulted in significant blood loss that is now controlled with prehospital treatment. When active hemorrhage is noted, the area should be promptly treated with compression, packing, or tourniquet placement. Assess tourniquets already in place for positioning and efficacy. In general, tourniquets are left in place until the initial assessment is performed and the patient's physiology is deemed normal or improving.

Exposure (E) is crucial when evaluating a patient with penetrating injury, especially from bullet wounds. The "x" in the xABCDE algorithm is a particularly important point when assessing patients with penetrating trauma**. Hemorrhage is the leading cause of preventable death. Complete exposure is vital to ensure that all wounds are identified.** In fact, the patient's back can quickly be assessed as they are moved from the emergency provider's stretcher to the emergency department stretcher. Though information obtained from the prehospital assessment is vitally important, it may be inaccurate and should be verified with visual inspection of the entire patient.

Bullet wounds can be very small and can be missed in skin folds, particularly in the axilla, groin, buttock creases, perineum, and scrotum. Carefully document the position and total number of bullet wounds or lacerations identified. Generally, the number of bullet wounds plus bullets identified on imaging should equal an even number. (This rule may not apply to patients who have been injured by bullets in the past.) **If the sum of wounds and retained missiles is an odd number, the physical exam should be repeated, and consideration should be given to widening the field of imaging. Also consider that bullets identified on imaging remote from where they entered the body may have embolized through vascular channels or be within the gastrointestinal tract.**

Many electronic medical records have avatars that allow mark-up for visually recording injuries**.** ■ **Figure 22-1** is an example of a diagram that can be used to mark the location of bullet injuries identified. Alternatively, narrative descriptions suffice. Note the size and location of periwound hematomas so they may be reassessed for expansion indicating ongoing bleeding. Evaluate the area around the wound for crepitus, bruit, and thrill. These findings could indicate injury to the aerodigestive tract or suggest vascular injury. Note the character of drainage from the wounds as well. In addition to blood, succus or cerebrospinal fluid drainage is possible**. Bullet wounds should not be blindly probed, as probing provides little helpful information and may exacerbate bleeding or further contaminate the wound.**

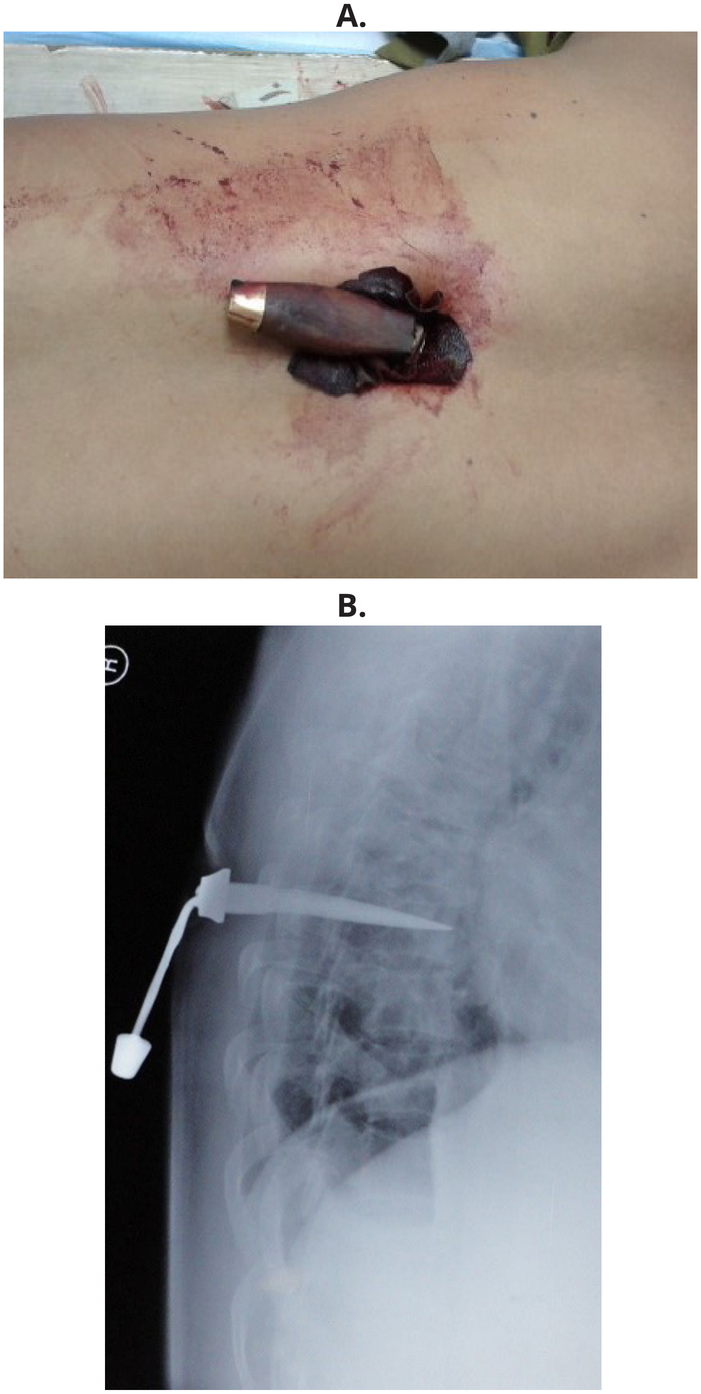
■ **Figure 22-1: Diagram Demonstrating Location of Bullet Wounds.**



Wounds that course in the vicinity of blood vessels can cause injury to arteries or veins. Perform a careful vascular assessment. Note whether a pulse is palpable, as well as the strength and character of the pulse. Use a Doppler to assess for blood flow when the pulse is abnormal or absent. Measure the injured extremity index or ankle-brachial index**. Should it measure <0.9, further assessment is necessary to exclude a vascular injury.** Venous injuries are trickier to diagnose. They may stop with compression and immobilization only to rebleed once activity is resumed, produce delayed hematomas, or result in deep venous thrombosis. Neurologic injury is also possible due to either concussive injury or transection.

Impaled objects should not usually be removed in the emergency department. Surgical consultation is needed. Impaled objects may tamponade bleeding or be firmly lodged in place. The operating room is the ideal place for removal. Large objects may require special manipulation or personnel to allow for safe removal or supplemental imaging. Imaging can assess depth of penetration and spatial relationships to critical structures (■ **Figure 22-2A** and ■ **Figure 22-2B**).

■ **Figure 22-2: Stab Wound to the Lower Thoracic Area of the Back.**
A. Patient presents with a stab wound to the lower thoracic area of the back. Note the blade is completely buried and the handle is bent. Clothing has been cut away. Note fragment of shirt present around the knife. **B.** Lateral spine plain x-ray showing the length of the blade and the bend of the handle.



HEAD AND NECK

PENETRATING HEAD TRAUMA

Penetrating head trauma can result in severe morbidity or mortality. In the US, firearms result in the largest percentage of deaths from traumatic brain injury (TBI). Generally, only 10% of patients with these injuries survive to reach hospital care. Of those who reach care, half will die in the emergency department. Survivors often face long-term neurological sequelae. The best outcomes require rapid assessment and early neurosurgical consultation. Patient assessment begins with the xABCDE, as usual. Patients should be resuscitated and treated aggressively, because outcome can't be predicted based only on external examination. Bullets can penetrate, perforate, strike tangentially, ricochet, or careen.

Bullets can also produce injury to the brain without penetrating the skull. Energy transfer from the projectile can result in TBI through blast or concussive effects. **Unlike nonpenetrating TBI, penetrating injuries to the cranium may produce massive external blood loss, resulting in hemorrhagic shock.** These injuries may involve the scalp, which has a rich vascular supply. Penetrating injuries to venous sinuses or meningeal or parenchymal vessels may manifest as external blood loss. In addition, coagulopathy from release of tissue thromboplastin can exacerbate bleeding. **Assess for bleeding from the wounds and treat with compression, oversewing or stapling to contain hemorrhage. Packing wounds is usually not advisable. Note whether brain matter is present.**

Rapidly assess the airway. Patients with depressed level of consciousness, loss of protective airway reflexes, obstruction, bleeding, or vomiting will need definitive airway control. Obtain intravenous or intraosseous access to administer blood, blood products, resuscitation fluids, and medications. Perform a brief and rapid neurological assessment before administering medications that will alter the neurological examination. Carefully inspect the scalp to identify areas of injury. Wounds can hide beneath hair, and it may be necessary to shave the area to fully appreciate the extent of injury. **Although penetrating injuries to the head can produce brain injury associated with high mortality and morbidity, the patient's outcome is not predictable in the first minutes following their presentation.**

Treat patients with clinical evidence of increased intracranial pressure with maneuvers to decrease it while maintaining cerebral perfusion pressure (see details in *Chapter 7, Disability: Neurological Assessment and Management*). Remember to give tetanus prophylaxis if needed and to give antibiotics, especially in cases where sinuses have been traversed by the injuring implement. **Aggressive treatment and resuscitation offer the patient the best opportunity for survival and good neurologic outcome.**

■ Box 22-2: Definitions of Potential Pathways of Bullets to the Head.

Penetrating	Entry wound with no exit wound
Perforating	Entry and exit wound with tract through the brain parenchyma
Tangential	Strikes the head obliquely without penetrating the brain tissue but may result in scalp lacerations, skull fractures, or cerebral contusions
Ricochet	Penetrating bullet that may bounce off the inner table of the skull one or more times
Careening	Penetrates the skulls and travels along the periphery of the cortex without entering parenchyma but has the potential to damage the dural venous sinuses

PENETRATING MAXILLOFACIAL TRAUMA

Penetrating maxillofacial trauma can include a spectrum of injuries ranging from minor to severe destruction. Anatomically, the area has a rich blood supply and is compact. Injury to neurological, ophthalmic, vascular, and axial skeletal structures are possible. Injury to the adjacent central nervous system is of great concern. The airway is also frequently compromised or at risk of compromise with penetrating injury.

Assessment begins with xABCDE. Bleeding into the oropharynx in a conscious and cooperative patient can be managed at least temporarily with upright positioning (when there is no need for spinal motion restriction) or reverse Trendelenburg positioning (when there is a need for spinal motion restriction) and suctioning while resources are assembled for definitive airway control. Airway control can be quite challenging in these patients. It is therefore important to be prepared to place a surgical airway.

Open wounds can be packed with rolled gauze or hemostatic gauze (if available) followed by circumferentially wrapping with an elastic or rolled bandage. Reduction of fractures aids in hemorrhage control. Patients with penetrating ocular injury should not have compression dressings applied. With the guidance of surgical consultants, tissues may be approximated to allow more effective tamponade.

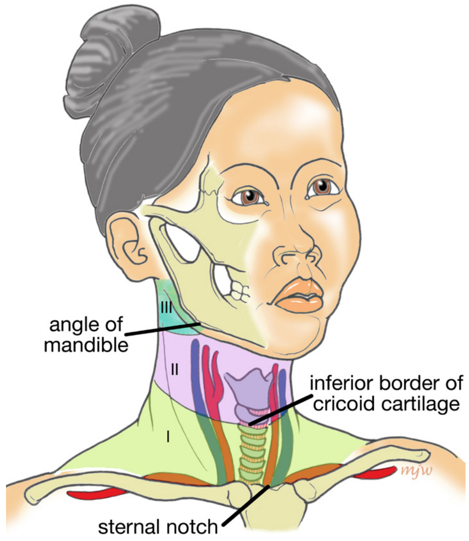
PENETRATING NECK TRAUMA

Injuries that penetrate the platysma are considered significant. Penetrating neck injury accounts for approximately 5%–10% of all trauma cases and mortality can be as high as 10%. Vascular injuries occur in up to 40% of penetrating neck injuries, and aerodigestive injuries occur frequently as well.

Historically, injuries to the neck have been separated into three zones. This was because assessment and treatment were based on the zone of injury. With the advent and availability of CT scanning, there is decreasing utility of this classification. Contemporary treatment is based on physiological presentation rather than anatomy.

Patients who display "hard signs" of injury are treated with urgent surgical exploration or angiography, while those displaying "soft signs" require further evaluation with imaging. Early surgical consultation is necessary regardless of presentation. The zone classification, although used less often now, provides a basis for discussion of the area of injury and possible injured structures. **■ Figure 22-3** outlines the zones of the neck. **■ Table 22-1** describes the zones of the neck with structures at risk of injury. It is important to remember that although a wound may be present in one zone, the penetration may extend to another zone or even another body cavity. The neck contains large blood vessels and important nerves that surround the airway, and airway compromise can result from direct injury, hematoma, swelling, or compression. **Bleeding from "closed" wounds (those with small openings that don't allow for packing) can sometimes be controlled using balloon tamponade.** **■ Figure 22-4** demonstrates a penetrating wound that created an internal carotid injury. When external compression fails to adequately control the bleeding, a urinary catheter can be inserted through the skin opening and inflated to provide tamponade while the patient is resuscitated and definitive care plans are made.

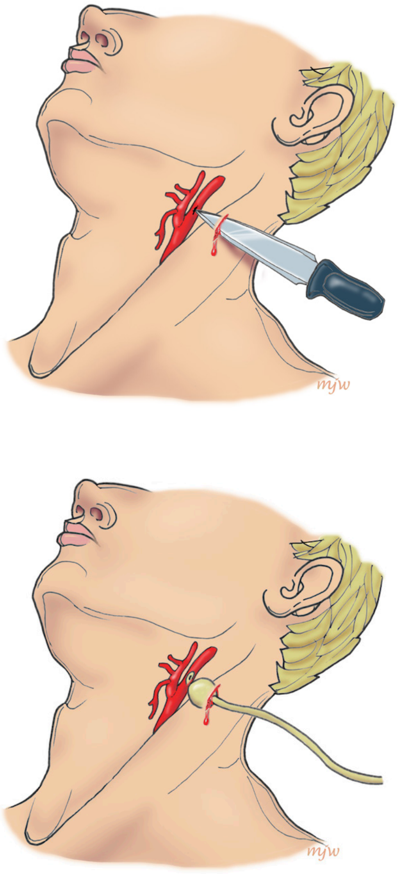
■ Figure 22-3: Anatomic Zones of the Anterior Neck. Zone I extends from the clavicles or sternal notch to the cricoid cartilage. Zone II extends from the angle of the mandible to the cricoid cartilage and Zone 3 extends above the angle of the mandible. Note the rich blood supply of the area.



■ **Table 22-1: Zones of the Neck and Basic Approaches to Injury.** The potential injured structures within each zone and basic approaches to injury.

Zone I	Extends between the clavicle/suprasternal notch and the cricoid cartilage (including the thoracic inlet). Surgical access to this zone may require thoracotomy or sternotomy. Major arteries and veins, trachea and nerves, esophagus, lower thyroid and parathyroid glands, and thymus are located in this zone.
Zone II	Lies between horizontal lines drawn at the level of the cricoid cartilage and the angle of the mandible. It contains the internal and external carotid arteries, jugular veins, pharynx, larynx, esophagus, recurrent laryngeal nerves, spinal cord, trachea, and upper thyroid and parathyroid glands. Access with open surgery.
Zone III	Extends between the angle of the mandible and base of skull. It contains the extracranial carotid and vertebral arteries, jugular veins, cranial nerves IX–XII, and sympathetic nerve trunk. Difficult to access with open surgery.

■ **Figure 22-4: Stab Wound to Internal Carotid Artery.** Demonstrates a patient with a stab wound to the internal carotid artery. If external compression fails to control bleeding and there is a small external opening limiting the utility of packing, placing a balloon-tipped catheter through the narrow opening and inflating it can produce enough tamponade to allow for rapid assessment, resuscitation, and transfer to an operating room.



Unlike patients with blunt trauma, patients with penetrating neck trauma or even with penetrating bony injury to the spine do not usually require spinal motion restriction with a cervical collar. The cervical collar may in fact obscure or delay evaluation of wounds present. These spinal injuries are usually mechanically stable, and manipulation of the head during intubation does not result in neurological dysfunction.

Airway assessment is dynamic. A normal airway with adequate breathing and ventilation can deteriorate to airway obstruction with ongoing bleeding or development of edema. Orotracheal intubation is the primary approach for an airway that is compromised but where normal anatomy is preserved. Videoscopic intubation (when available) is valuable when the anatomy is distorted and a difficult intubation is anticipated. The expertise to perform a surgical airway should be available as well. Immediate surgical airway is required for patients with severe upper-airway distortion, massive midface trauma with inability to visualize the glottis because of edema, bleeding, or anatomical disruption. Direct tracheal intubation is required in patients with large lacerations of the neck with tracheal transection.

Once the primary survey is completed and the patient's physiology is normalized or improving, thorough examination of the neck is needed. Reassess hematomas to determine if they are expanding. Note the location and number of wounds present. Assess any drainage from the wounds for saliva or cerebrospinal fluid. Stabilize impaled objects if not already done. Reassess areas that were packed or tamponaded for ongoing control of bleeding. Listen for bruits. Evaluate the airway position. Palpate for evidence of crepitus. Note if there is evidence of blowing air from the wound (may develop over time). In patients who are awake and not intubated, access the voice quality and strength. Assess whether there is dysphagia or odynophagia. Perform a neurological assessment, including assessment of cranial nerves, motor and sensory examination, and evaluation for Horner's syndrome (miosis, ptosis, and anhidrosis). **An altered mental status may indicate vascular injury with cerebral hypoperfusion.**

PENETRATING THORACIC TRAUMA

The hemodynamic presentation of patients with penetrating chest trauma can vary from stability to cardiac arrest. Like with blunt trauma, most patients presenting with penetrating thoracic trauma require only tube thoracostomy. **A higher proportion of patients with penetrating trauma will require operative intervention (15%–30%, compared with <10% with blunt thoracic trauma).** Penetrating trauma is generally more lethal than blunt trauma, accounting for 3% of trauma-related deaths in the US. Injuries to the chest wall, lungs, heart, great vessels, tracheobronchial tree, esophagus, and diaphragm can occur with penetrating injury. **Injuries that result in significant blood loss, cause loss of the airway or interfere with ventilation, produce tamponade, or result in tension pneumothorax are the most rapidly fatal and require rapid assessment and treatment.**

Evaluation begins with the usual xABCDE approach. Penetrating thoracic trauma can be the source of massive hemorrhage, but it is usually not visible externally. More often, patients present with one of the following: clinical evidence of shock from blood loss; tension physiology combined with blood loss; cardiac tamponade; or inadequate oxygenation and ventilation. These patients require rapid resuscitation and treatment to avoid progressing to cardiac arrest. Consult surgery early. **Though intubation and mechanical ventilation may be indicated, it is important to administer volume resuscitation to avoid circulatory collapse, which may accompany the administration of drugs to assist intubation or the provision of positive-pressure ventilation.** Tension physiology should be treated with rapid decompression of the chest with finger thoracostomy followed by tube thoracostomy. Continued shock despite adequate decompression of a hemothorax is an indication for surgical exploration. A second tube may be required in patients with persistent pneumothorax and large air leaks.

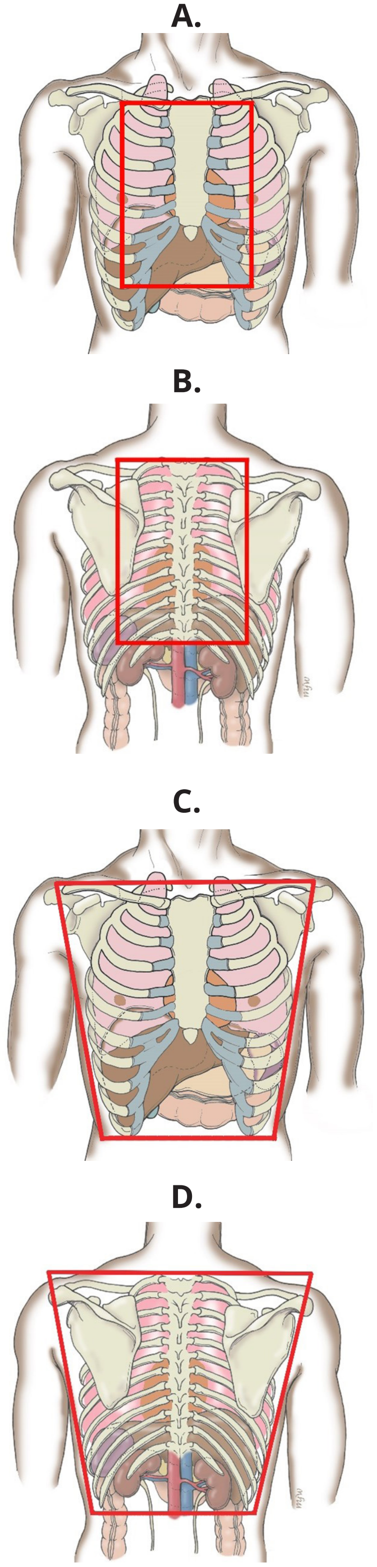
Note the location of wounds and mark them with a radiopaque marker (paper clip or ECG lead). Remember that wounds below the nipples anteriorly or the scapula angle posteriorly risk infradiaphragmatic injury as well. Penetrating injuries that occur within the "cardiac box" should cause concern for cardiac injury **■ Figure 22-5**. The box is defined as between the nipples laterally, the clavicles superiorly, and the costal margins inferiorly. Recently, it has been noted that patients presenting with gunshot wounds to the chest may have an expanded cardiac box that includes the anterior and posterior thorax. **■ Figure 22-5A** and **22-5B** represent the standard "cardiac box" and **■ Figures 22-5C** and **22-5D** represent the expanded "cardiac box." **Maintain a high index of suspicion for cardiac injury in patients with bullet wounds that are outside the typical cardiac box.**

Patients with cardiac injury may present without overt signs of cardiac tamponade such as the typical Beck's triad (distended neck veins, muffled heart sounds, and low cardiac output). They may appear asymptomatic, may be hemodynamically unstable without evidence of Beck's triad, or may present with cardiac arrest. Patients sometimes present with inability or unwillingness to lie supine. **Do not rely solely on the absence of clinical signs to exclude the diagnosis of tamponade.** Patients presenting with cardiac arrest or profound hypotension require emergency department thoracotomy, providing cardiac arrest has not exceeded 15 minutes.

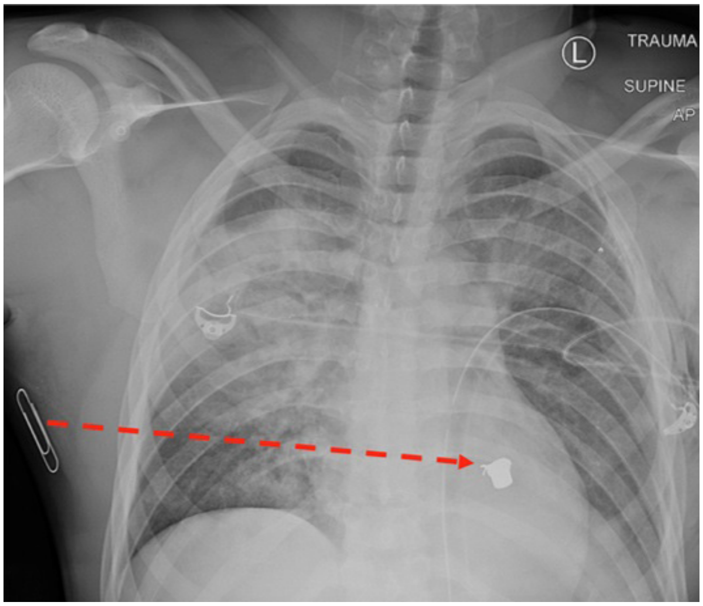
Patients with transmediastinal ballistic injury require special consideration. Patients with these injuries who present with hemodynamic instability require rapid identification and surgical intervention. These injuries are associated with high mortality (in excess of 50%) because of injury to thoracic vascular structures. Patients with these injuries who are hemodynamically stable on presentation, on the other hand, require surgical intervention 7%–33% of the time. Imaging with eFAST and chest x-ray will identify hemo- or pneumothoraces and establish trajectories. eFAST can also demonstrate pericardial effusion. **■ Figure 22-6** is a chest x-ray of a patient with a transmediastinal trajectory that is hemodynamically stable. Note the paper clip marking the wound on the right hemithorax and the bullet visualized in the left chest. Request surgical consultation early.

Further evaluation with chest CT in stable patients can provide spatial relationships with the path of the projectile and identify injury to structures. Further testing with dedicated angiography, endoscopy to evaluate the esophagus and airway, and/or an esophagram may be needed to identify injuries not fully evaluated with CT scan. Pericardial window in the operating room can evaluate for cardiac injury in stable patients or those requiring exploration of other body regions.

■ Figure 22-5: Cardiac Box. A. Demonstrates the traditional representation of the cardiac box extending from the clavicles superiorly, costal margins inferiorly and nipples laterally. **B.** Demonstrates the traditional representation of the cardiac box from the posterior view. **C and D.** Demonstrate anterior and posterior views of the expanded cardiac box that includes the back and extends laterally to the anterior and posterior axillary lines.



■ **Figure 22-6: Chest X-ray Bullet Wound to the Right Chest.** This chest x-ray was obtained after this patient presented with a bullet wound involving the right chest. Note a paper clip was placed to localize the bullet wound on right lateral chest. A bullet is seen in the left chest. Notice the opacity of the right lung demonstrating contusion. A left chest tube can also be seen directed inferiorly.



Stable patients with penetrating chest trauma require reassessment for evolution of injuries. Evaluation with ultrasound, plain x-ray, and CT scan can identify injuries that require intervention or admission. Bronchoscopy or contrast studies may be useful in identification of injury to specific structures. Chest x-ray, eFAST, and cardiac evaluation are often performed during the initial assessment in patients with penetrating thoracic injury. Tetanus prophylaxis (if needed) and antibiotics are given, particularly for patients who require tube thoracostomy.

PENETRATING ABDOMINAL/PELVIC TRAUMA

The evaluation of the patient with abdominal penetrating trauma begins with the xABCDE. **It is important to identify all penetrating wounds and to carefully mark and document their location. It is not necessary to know which wounds are exits or entrances.** Simply noting the number of wounds and their location avoids confusion. Explain to the patient the need to carefully examine their entire body to exclude other wounds and the need to perform a rectal examination. Provide as much privacy as the urgency of the situation allows.

Turn patients early in their evaluation to evaluate the posterior torso for wounds. Look carefully at the axilla, perineum, genitalia, and skin folds. Perform a digital rectal exam using lubricated, clean, gloved finger. Note presence of blood, perianal sensation, and sphincter tone. Evaluate for evidence of hematoma, evisceration, active bleeding, or bubbling of air or drainage of succus from the wound. Impaled objects are generally left in situ. Cross-sectional or planar imaging can show depth of penetration and relationship to critical structures. Place markers at the level of the wounds. When radiographic evaluation is utilized, the markers help identify the level of the wounds.

The abdomen includes the anterior abdomen, flanks, back, and pelvis. The flank and back have more protection from injury, with thick musculature and bones protecting the internal contents, while the anterior abdomen is protected by the much less robust anterior abdominal musculature. Look for abdominal distension. Distension may indicate a large hemoperitoneum. Large volumes of blood can pool before abdominal distension is apparent. Look for clinical signs of shock. **Patients with shock and transabdominal penetrating trauma require immediate surgical consultation and intervention.** FAST examination is performed as part of the primary survey and can be repeated to evaluate for delayed bleeding. Evaluate for peritonitis. **Other "hard signs" that should prompt immediate abdominal exploration include peritonitis, evisceration, hematemesis, and blood per rectum. Free intra-abdominal air may identify hollow visceral injury and indicate a need for abdominal exploration.** Tenderness is expected around wounds and can be challenging to differentiate from peritonitis, especially in patients with multiple wounds. Hematuria is another clue that there has been injury to the genitourinary tract. Indications for exploratory laparotomy are listed in ■ **Box 22-3.**

■ **Box 22-3: Indications for Exploratory Laparotomy After Penetrating Trauma.** FAST, Focused Assessment with Sonography for Trauma; DPA, Diagnostic peritoneal aspiration.

Indications for Exploratory Laparotomy

- Hemodynamic instability
- Peritonitis
- Bleeding from rectum
- Aspiration of blood via nasogastric tube or hematemesis
- Evisceration of bowel
- Impalement
- Positive FAST findings
- DPA (diagnostic peritoneal aspiration) aspirate of succus or > 10 cc of blood
- Free air on imaging study

Balanced resuscitation occurs simultaneously. Before definitive hemorrhage control is achieved, it may be advantageous to maintain a lower mean arterial pressure. High pressures can actually increase hemorrhage. Whole blood and blood products are the resuscitation fluids of choice. Massive transfusion or hemorrhage protocols are initiated. Triggers for initiating massive transfusion protocols include Assessment of Blood Consumption (ABC) score ≥ 2 (■ **Box 22-4**). Antibiotics and tetanus immunization (if needed) should be provided.

■ Box 22-4: Assessment of Blood Consumption (ABC) Score. An ABC score is derived from easily attained measures including SBP, HR, +FAST and presence of penetrating torso trauma. A score of 2 or more increases chance of needing massive transfusion. ABC, Assessment of Blood Consumption; SBP, Systolic blood pressure; HR, Heart rate; FAST, Focused Assessment with sonography for trauma.

ABC score

Score < 2 suggests unlikely need for massive transfusion

SBP ≤ 90	+1
HR ≥ 120	+1
+ FAST	+1
Penetrating Torso Injury	+1

In more stable patients, the abdomen is thoroughly assessed during the Secondary Survey. Reconfirm the location and number of penetrations. Clean and dress small wounds. Ensure eviscerated tissue is kept moist and covered and impaled objects are well supported. Slash wounds can be closed if surgical exploration is not needed. Bullet wounds are generally cleaned and left open. Reassess for expansion of hematoma, bleeding, or drainage from the wound. Not all abdominal or pelvic penetrating wounds will reach the intraperitoneal space and require operative intervention. The frequency of injury to organs from penetrating mechanisms include the small bowel (50%), large bowel (40%), liver (30%), and intra-abdominal vascular structures (25%). **Decisions regarding surgical and nonoperative management rests with the surgical team, underscoring the need to involve surgeons early in the evaluation and decision-making regarding patients with abdominal and pelvic penetrating injuries.**

When nonoperative management is considered, imaging with a CT scan can provide information regarding the trajectory of penetration and identify specific injuries to organs, viscera, blood vessels, or bones. When CT scanning is not an option, frequent reexamination can detect changes that could merit operative exploration. Stab wounds to the anterior abdomen can be locally explored to determine whether penetration of the abdominal cavity has occurred. If penetration has occurred, further evaluation, operation, or observation is indicated. Availability of personnel to perform serial examinations and operating room availability are key considerations.

PENETRATING EXTREMITY TRAUMA

When evaluating the patient with a penetrating injury to the extremity, control of life-threatening hemorrhage should be quickly assessed. Initially utilize direct pressure or packing. If these techniques fail, if there are multiple sites of significant bleeding in the extremity, or if there is a need to free up hands for participation in other tasks, a tourniquet can be placed above the area of injury. Once hemorrhage is controlled and the primary survey is complete, identify all wounds and document their position. Take note of any proximity to neurovascular structures. Look for hematomas, tissue destruction, and bony deformities.

Evaluate pulses throughout the extremity. When pulses are not palpable or are diminished, use Doppler to determine if there is flow. Motor and sensory evaluation should also be performed and documented. **Remember that patients with tourniquets in place will have sensory and motor deficiencies, and pulses should not be palpable below a tourniquet.** When a patient presents with a field tourniquet, assess when it was placed, whether it is positioned appropriately, and if it has been placed effectively. If you can place a finger between the tourniquet and the skin, it is not effective and may be functioning as a venous tourniquet and exacerbating hemorrhage. If you determine that the tourniquet is ineffective and there is ongoing bleeding, place another tourniquet above the first. **When the primary survey is completed and the patient is hemodynamically normal, the tourniquet can be assessed for conversion to a hemostatic or pressure dressing. see *Chapter 14, Initial Assessment: Secondary Survey*, for full details. Ideally, surgical consultants are present during this process.**

Obtain plain x-rays to evaluate the position of foreign bodies and document presence of fractures. Note the position of projectiles and fragments relative to the course of blood vessels. An injured extremity index is performed in the same manner as an ankle-brachial index. When injuries involve the upper extremity, comparison is made between the injured and noninjured limb. **Further evaluation of vascular structures is indicated when the index is < 0.9. Surgical consultants should be involved early, as patients with vascular compromise are at risk of tissue loss and amputation without timely intervention.** Serial evaluations of injured extremities to assess for expansion of hematomas, active bleeding, and development of compartment syndrome are performed.

Keep in mind that even when arteries aren't injured, venous injuries can result in troublesome bleeding and hematomas. Providing compression using elastic bandages can aid hemostasis. Vascular injuries can present with clear and obvious signs of injury or more subtle signs. Those with obvious signs of injury require urgent surgical evaluation and expedient operative intervention. Those with more subtle signs also require time-sensitive surgical evaluation but are usually stable enough to allow for additional evaluation with imaging. Hard and soft signs of vascular injury are listed in ■ **Table 22-2**.

Table 22-2: The Hard and Soft Signs of Vascular Injuries. ABI, Ankle brachial index; IEI, Injured extremity index.

Hard signs	Soft signs
• Active pulsatile bleeding • Rapidly expanding hematoma • Pulselessness • Acute ischemia • Vascular thrill • Bruit • Persistant hypotension	• Pulse deficit • Nonexpanding hematoma • Pallor of extremity • Neurological deficit • History of extensive bleeding at the scene • Abnormal ABI or IEI

ADJUNCTS TO ASSESSMENT

In patients who are hemodynamically normal, the decision to utilize imaging to further characterize injuries can be helpful. Bedside Doppler and arterial duplex studies can identify injuries that require further imaging in patients with extremity or neck injuries. Extended FAST can be performed during the primary survey and repeated at any time to assess the evolution of injuries. Pneumothoraces can develop or expand over time, as can pericardial effusion and intra-abdominal hemorrhage.

Localize foreign bodies using plain x-rays. Place radiopaque markers over bullet wounds before imaging. This will clarify relationships of injured structures to bullet paths. **The number of bullet wounds plus bullets should generally, when summed, be an even number, except in the case of bullets retained from prior injuries.** Foreign body series are obtained to localize any bullet that has not passed through the body; in the case of abdominal injury, this includes chest, abdomen, and pelvis x-rays. The x-ray plate is oriented in a landscape projection and must include skin from one side of the body to the skin of the other side. In patients with higher body mass index (BMI), this may require multiple flat plates to ensure no projectile is missed. When the number of bullets and wounds don't add to an even number and there is no retained bullet from a prior injury, the area imaged must be expanded. **Bullets located in unexpected places may have reached their location through embolization from vascular injury or may be within the gastrointestinal tract.** CT angiography (when available) can identify lesions that require further characterization with angiography or open or endovascular treatment. Specialist consultation should be involved in decision-making about imaging and need for surgical intervention.

Caution must be exercised in the evaluation of patients with thoracoabdominal penetrating injuries. Diaphragm injuries can be easily overlooked and present the potential for future problems for the patient. The surgical team will determine next steps in the diagnosis of these injuries. Diagnostic laparoscopy is commonly used to evaluate injuries that involve the left side. The liver offers some protection on the right side.

Diagnostic peritoneal aspiration can be used in very specialized circumstances or settings without availability of CT scanning. Patients who are either hemodynamically stable with unclear transabdominal trajectory or who have injuries in other body areas that require operative treatment may benefit from diagnostic peritoneal aspiration. A foley catheter and nasogastric tube are inserted. The peritoneal cavity is percutaneously accessed and aspirated to evaluate for the presence of blood or succus.

Identified fractures require splinting, as outlined in the *Chapter 10, Musculoskeletal Trauma*. **Foreign bodies that may be located in a joint require specialist consultation to determine the need for further imaging or surgical removal.** Antibiotic prophylaxis is needed, as these are open fractures.

Generally, gastric tubes and urinary catheters are placed as needed to decompress the stomach and bladder. Blood aspiration may indicate an injury that requires further characterization or treatment.

Laboratory tests should be reviewed. Elevated transaminases may indicate hepatic injury, amylase or lipase may indicate pancreatic or gastrointestinal injury, and hematuria may indicate injury to the genitourinary tract. **Metabolic acidosis or hyperlactatemia in otherwise hemodynamically normal patients may indicate blood loss and requires intervention and follow-up.**

TRANSFER CONSIDERATIONS

If the patient's needs exceed the capacity of the treatment facility, transfer should be considered. Initial stabilization through hemorrhage control, resuscitation, and treatment of immediate life threats is ideal. Prepare for the possibility of hemodynamic deterioration during transport and have the necessary resources to continue resuscitation and monitoring. **In the case of a patient with abdominal penetrating injury presenting in shock, immediate operative treatment to achieve hemostasis prior to transfer may be considered if surgical capabilities permit.**

SPECIAL POPULATION CONSIDERATIONS

Elderly patients may have higher basal blood pressure and blunted heart rate response to hemorrhage. Injuries that traverse soft tissue can produce unexpected bleeding because of the loss of integrity of the connective tissue. Calcified vessels are easily damaged and harder to occlude. Overresuscitation can lead to respiratory complications. Low hemoglobin may be poorly tolerated.

Trauma is the leading nonobstetrical cause of death in pregnancy, representing 6%–7% of all maternal deaths. Fetal mortality reflects the severity of maternal injury. Fetal demise occurs in 40%–65% of pregnant patients with penetrating trauma. The higher position of the diaphragm in late pregnancy increases the risk of abdominal injuries with low thoracic penetrating wounds. Overall, maternal visceral injuries from penetrating trauma are decreased later in pregnancy due to the uterus displacing maternal viscera toward the upper abdomen as it enlarges; clinicians should still be cautious, particularly with penetrating injuries to the upper abdomen/lower thoracic areas. The uterus, however, is at significantly increased risk of injury from penetrating trauma in late pregnancy, with fetal mortality as high as 70%. Firearm injury is 7.8 times more likely than a motor vehicle crash to result in death in pediatric patients. Pediatric patients with gunshot wounds are more likely to require immediate surgery.

PRACTICE ENVIRONMENT CONSIDERATIONS

In environments where resources are limited, it is important to understand which tools are available for assessment, resuscitation, and definitive care. Blood availability for resuscitation is severely limited in some areas. This makes limiting blood loss vitally important. Allowing blood pressure to remain low (mean arterial pressure 60 mm Hg) may prevent cycles of fluid resuscitation initially increasing blood pressure, leading to bleeding with a drop in blood pressure. Crystalloid fluids can be used in limited capacity in environments without blood transfusion resources. Vasopressor use can be considered but is not a substitute for hemorrhage control or blood transfusion.

External hemorrhage that does not respond to pressure or packing should be treated with a tourniquet. Tourniquet times of < 2 hours have not been associated with tourniquet-related complications. Tranexamic acid should be given for injuries that have occurred within 3 hours. When eFAST is not available, techniques like diagnostic peritoneal lavage or diagnostic peritoneal aspiration can be used to evaluate for intraperitoneal bleeding. Selective exploration of penetrating abdominal trauma is not safe in all settings. In austere settings where further evaluation and potential nonoperative management are unsafe or impractical, immediate exploration remains essential. This setting includes battlefield environments or other resource-limited scenarios where advanced imaging modalities are unavailable, close observation is unfeasible, or the resources and expertise necessary for safe nonoperative management are insufficient.

CHAPTER SUMMARY

Penetrating injuries, resulting from unintentional accidents, violence, or self-harm, contribute to a significant portion of the estimated 4.4 million injury-related deaths globally each year, with their prevalence and impact varying greatly by location and with certain populations, especially young men in poverty, being particularly vulnerable. Severe blood loss associated with penetrating injury produces a series of hormonal responses aimed at maintaining homeostasis that result in vasoconstriction and decreased organ perfusion.

Knives and bullets are commonly recognized causes of penetrating trauma, but other objects like bone fragments, shrapnel, nails, and glass can also inflict serious injuries. These injuries may result in external hemorrhage that can be treated with compression, packing, or tourniquet application. Internal injuries are more difficult to identify and may require evaluation with eFAST, x-ray, CT scanning, or in some cases immediate surgical exploration. When the capacity to manage a patient's injuries is lacking, transfer the patient to a center capable of managing the known or suspected injuries.

KEY LEARNING POINTS

- **Listen carefully to history but examine thoroughly to ensure no injuries are missed. Carefully assess areas that can hide small injuries, like the scalp, perineum, axillary, gluteal, and thigh folds. Document the number and position of injuries identified.**
- **Repeatedly reassess for deterioration. Look for hematomas that expand with time. Assess the airway and breathing for evidence of compromise.**
- **Be aware of the time sensitivity of injuries, particularly those associated with bleeding or ischemia.**
- **Mark injuries before imaging.**
- **Initiate massive transfusion protocols for patients in shock. If resources aren't available to care for the patient's injury, begin transfer processes early.**

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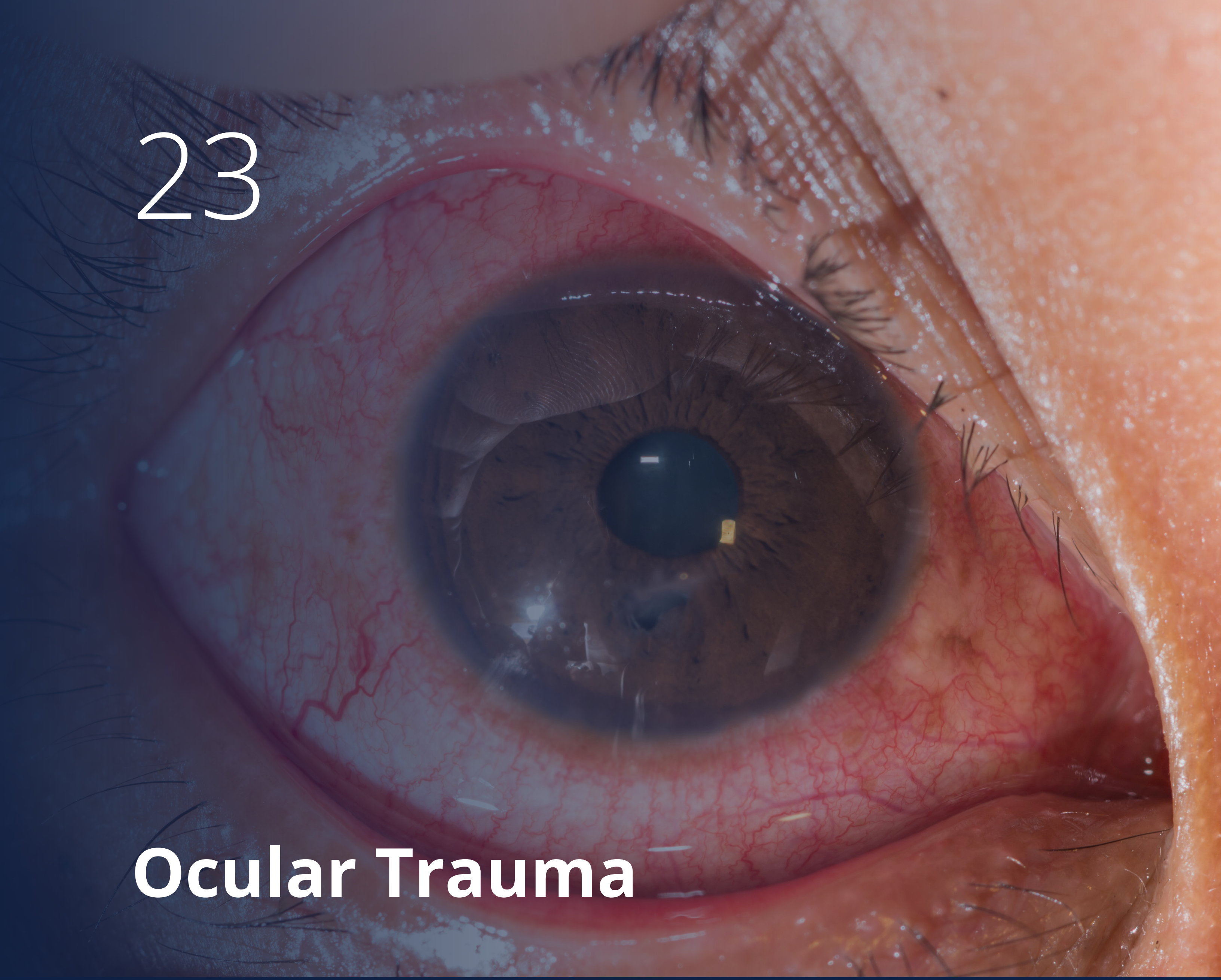


23

Ocular Trauma

OBJECTIVES

After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Explain basic orbital and ocular anatomy (learn terminology)
2. Describe a systematic examination of the orbit and its contents
3. Identify the main ocular vital signs
4. Learn how to irrigate the eye in case of chemical exposure
5. Discuss the basics of canthotomy and cantholysis procedures
6. Understand how to manage an open globe
7. Describe the fluorescein dye test and its utility
8. Categorize populations at risk for muscle entrapment and how to screen for it
9. Summarize the characteristics of lid lacerations that require referral to a specialist

23

Ocular Trauma

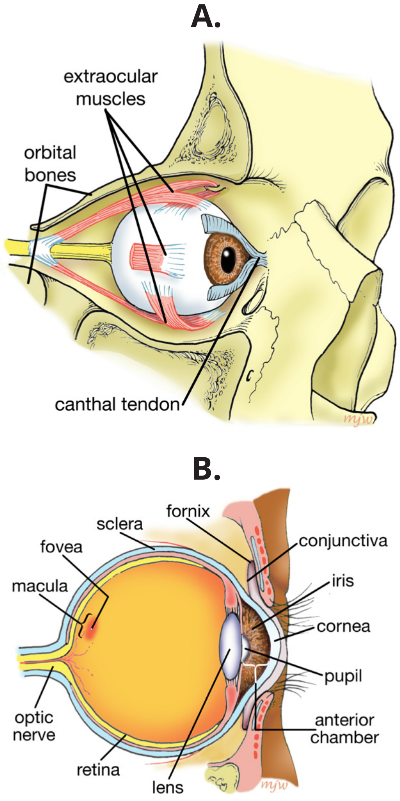
CHAPTER STATEMENT

Patients with ocular injuries are treated within the context of the ATLS initial Assessment. After addressing immediate life threats, attention should rapidly turn to determining if an ocular injury requires emergent treatment and ophthalmologic consultation. Often, initial treatment (e.g., eye irrigation after a chemical burn) can be initiated while formal consultation is pending. Delays in addressing ocular injuries can result in significant visual disability or blindness.

INTRODUCTION

In emergency medicine, the mantra "life, limb, or eyesight" describes what constitutes a true medical emergency. Although emergent medical care has changed with time, this concept still holds. Once immediate life threats have been addressed, clinicians should rapidly turn their attention to limb threats, as well as to injuries to the globe that might result in blindness or significant visual disability if not treated within the first few hours after onset. This chapter focuses on those types of injury. One must understand the fundamentals of the eye exam after injury, which begins with a review of basic eye anatomy (■ **Figure 23-1A** and **B**).

■ **Figure 23-1: Ocular Anatomy. A. Extraocular Muscles and Orbital Bones.** Understanding ocular anatomy can assist the clinician in the diagnosis of such entities as extraocular muscle entrapment, which occurs when extraocular muscles and other soft tissues become trapped in an orbital fracture and can lead to eye movement limitations, pain, diplopia, and other visual disturbances. **B. Ocular anatomy.** Understanding the relationships between the structures of the eye and their locations assists the clinician in performing an effective eye exam and recognizing threats to sight, such as chemical injury, open globe, or orbital compartment syndrome.



ANATOMY

The cornea is the transparent layer that forms the anterior boundary of the space known as the *anterior chamber* (AC), and it is contiguous with the sclera. Within the globe, the lens divides the eye into anterior and posterior segments. The anterior segment includes the cornea, sclera, conjunctiva, iris, and lens. The space between the cornea and iris is the AC; aqueous humor (a solution of sodium, chloride, and other ions) fills the AC. The posterior segment of the globe is between the lens and the retina; vitreous humor (a clear, jelly-like substance) fills the posterior segment. The optic nerve is at the back of the eye; it travels through the muscle cone and orbit and into the brain.

The globe includes the attachments of the extraocular muscles to the sclera. Epithelium-lined tissue known as the *conjunctiva* covers the muscles and sclera; it extends from the cornea-sclera junction over the Tenon's fascia layer and the sclera and then turns to cover the inside of the eyelids. The extraocular muscles join together to make a "cone." A fascia-like sheath called Tenon's capsule surrounds the cone, limiting the ability of muscles to expand (bleeding in this area may produce an intraconal compartment syndrome). The globe-muscle cone complex sits in the orbit, a pear-shaped cavity formed by bones that separate the orbital compartment from the sinuses and brain tissue. The eyelids have tendinous attachments (canthal tendons) medially and temporally on the bony orbit, which keep the globe from moving forward. This arrangement creates another space with limited expansion where extraconal compartment syndrome can occur.

Like all other evaluations, the assessment of ocular trauma includes a focused history and physical examination. The patient's preinjury comorbidities and vision history may be pertinent. Accurately assessing ocular trauma can change the patient's disposition, especially when emergent ophthalmic care is unavailable.

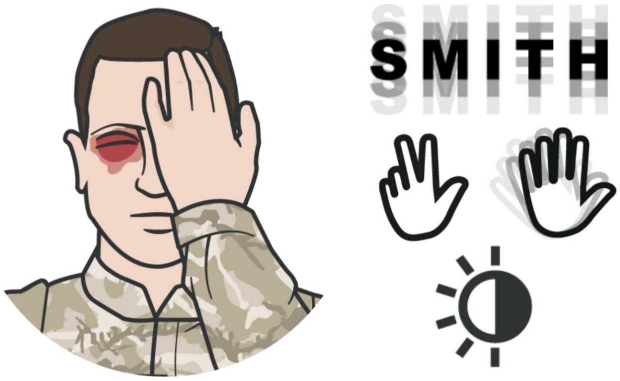
PHYSICAL EXAMINATION

When possible, every eye exam should obtain and document the eye's three "vital signs": vision, intraocular pressure, and pupils. These functions will give the clinician critical information about the essential health of the eye. In addition, physical examination includes the anterior and posterior segments of the eye. As in any medical exam, care should be taken so as not to exacerbate any present injuries.

VISION

A vision exam can be as simple as holding up a near-vision test card or reading material at the appropriate distance and recording the vision in each eye. Always note if the patient usually wears glasses or contact lenses and, if so, whether for distance or near (reading) vision. If a refractive error is known but the patient does not have glasses, ask the patient to look through a pinhole, which minimizes the refractive error, and recheck the vision. To make a pinhole, take a piece of paper or cardboard and use a ballpoint pen or paper clip to make a hole of about 0.2 mm in the center of it. If a professional pinhole occluder is available, use it to obtain slightly more accurate results. If unable to read letters or symbols, ask the patient to count fingers and note the distance from the patient's face. If unable to count fingers, ask the patient to recognize a hand waving and its direction (horizontal or vertical movement). If unable, assess if they can see a bright light moving on and off the eye. Remember: check each eye separately. After checking vision, patients who present with contact lenses should have them removed.

■ **Figure 23-2: Vision Assessment.** Vision quality is a "vital sign" of the eye. Depending on the resources available, it may be assessed with vetted tools, or by asking the patient to read available printed materials, count fingers being displayed, and/or indicate areas of light and dark. Each eye should be tested separately.



INTRAOCULAR PRESSURE

Handheld tonometry devices are now available in many emergency rooms. These gauges have improved the clinician's ability to check eye pressures in diverse patient situations. When using handheld tonometry devices, open the eyelid while being careful not to push on the globe, because doing so can falsely elevate the eye pressure. Ensure the fingers retracting the eyelids rest on the bony orbit. Always obtain 2–3 measurements of each eye at the highest reliability percentage on the tonometer (normal eye pressure is 8–21 mm Hg). The "data" or "%" reading on the pen indicate the likelihood that this reading is accurate. It is important to note that readings can vary with mechanical ventilation, Valsalva maneuvers, and accidental pressure on the globe during eye-opening. For nonsedated patients, anesthetize the eye with topical anesthetic ophthalmic drops (e.g., proparacaine).

If a tonometer is not available, you can estimate whether eye pressure is elevated by gently pressing with two index fingers on each side of the eye with the eyelids closed. To compare to a baseline, press on your eye or the patient's unaffected eye in the same manner and note if there is a difference. Most importantly, evaluate whether the patient has a firmer eye on the injured side. A precise measurement may not be possible, but knowing there is a difference or abnormality can be helpful. **If an open globe is suspected, do not check the eye pressure, because you might force more intraocular contents from the eye.** In such cases, check visual acuity and conduct a visual inspection only.

PUPILS

Pupils should be equal, round, reactive, and without an afferent pupillary defect. A pupil can enlarge due to blunt trauma (e.g., pupillary sphincter tear), past surgery, and other ocular disease processes. When an abnormal pupillary exam results from an ocular cause alone, the pupil often retains some reactivity to light, even though it is a different size. Such a patient's medical history should reflect a positive past ocular history; if it does not, further investigation and examination are necessary to evaluate for intracranial pathology. A sluggish or poorly reactive pupil indicates an ocular, orbit, or brain issue that needs further work-up.

ASSESSMENT OF OCULAR AND PERIOCULAR TRAUMA

Once systemically stabilized, a trauma patient deserves an evaluation for ocular and periocular trauma early in the overall assessment. Assessment begins upon coming into visual contact with the patient. A gross visual inspection of the facial area can determine if there is a likelihood of ocular or periocular injury. Visually evaluate if bruising, swelling, bleeding, lacerations, foreign bodies, or evidence of chemical (liquid or solid) exposure exists around the eyelids, forehead, or face. These are signs you may have to deal with a potentially blinding chemical injury, orbital compartment syndrome, ruptured or open globe, traumatic intraocular bleeding with elevated eye pressure, orbital fracture with muscle entrapment, or eyelid lacerations, which can also involve the lacrimal drainage system.

CHEMICAL INJURY

If there is a chemical exposure, emergent action is needed. **Chemical burns are true ocular emergencies and require treatment as soon as the patient arrives.** Ocular irrigation should not be delayed while waiting to speak with the ophthalmologist. Initial management involves copious irrigation of the affected eye, which requires little equipment. Ideally, a liter of normal saline or lactated Ringer's (use tap water only when sterile solutions are unavailable) connected to a Morgan lens allows for proper ocular irrigation. Place the lens in the eye and tilt the patient's head so the fluid runs out toward the temple (not into the other eye).

If a Morgan lens is unavailable, cut IV tubing bluntly to hold over the globe to maximize flow. When possible, the patient can hold the tip of the tubing on the nasal aspect of the eye so the water runs out of the eye. When both eyes require irrigation, you can connect a nasal cannula to fluid and place it over the bridge of the nose so it drains into both eyes. When none of this equipment is available, use any reasonable technique to rinse the eye (■ **Figure 23-3**).

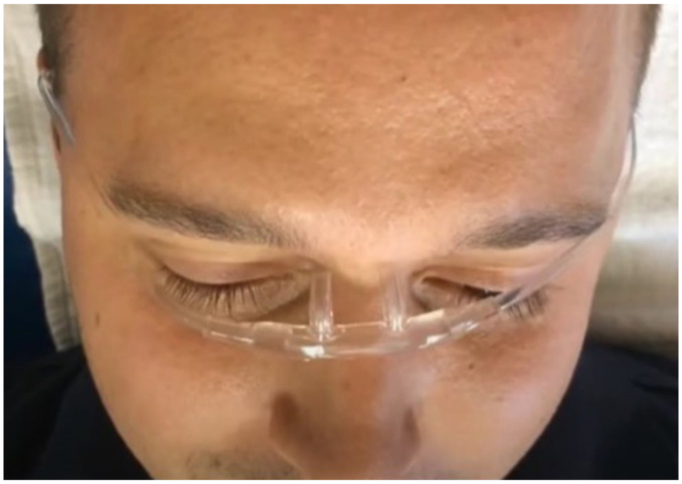
While flushing the patient's eye, obtain details about the chemical. For example, is it an acid or base, a liquid, a powder, or another solid material? Alkaline solutions are usually more damaging to the eye and often require more flushing to normalize the pH (7.0). Powders have small granules that can readily get stuck in the eye's superior and inferior fornices (deep spaces behind the eyelids). This situation sometimes requires inverting the eyelids and directly flushing with saline through a 10 cc syringe to dislodge the granules.

After each liter of solution or about every 30 minutes, stop the fluid, wait 5 to 10 minutes, and check the pH of the tears. While you are waiting, it is ideal to start the eye exam. You may stop irrigating the eye when the pH is neutral (near 7.0). If the pH is not neutral, continue this irrigation cycle, flush the fornices, and recheck pH until the tears are neutral. The process may require hours and liters of saline, so patience and perseverance are crucial. If you doubt chemicals remain, flush until the ophthalmologist arrives to examine the patient. Based on the ophthalmic exam, treatment will likely include antibiotic ointments, oral pain medications, and possible drops for inflammation and elevated eye pressure.

COMPARTMENT SYNDROME

If trauma to the facial area results in an orbital hemorrhage with compartment syndrome, the examination may show bruising with tense, firm eyelids, a protruding eye (proptosis), and firmness to palpation through the eyelids. The patient likely notices decreased vision, the pupil may be poorly reactive, there will probably be blood under the conjunctiva, and the eye will have limited motility. If you can check intraocular pressure, it will likely measure as elevated. Urgent treatment with a canthotomy and cantholysis is required if an orbital hemorrhage with compartment syndrome is present.

■ Figure 23-3: Ocular Irrigation Using A Nasal Cannula. Although irrigation of the eye is ideally done using a Morgan lens, other techniques such as using the prongs of a nasal cannula, or IV tubing held over the globe may also be used. For suspected chemical injuries, irrigation usually is performed for at least 30 minutes; it should not be delayed waiting for an ophthalmology consultation.



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Permanent vision loss can occur after 90 minutes of impaired blood supply, so immediate treatment is imperative. If you are concerned about a retrobulbar hemorrhage causing a compartment syndrome, immediately perform a canthotomy and cantholysis (or contact someone who can walk you through it). Canthotomy alone (i.e., cutting the dermis only) does *not* improve retrobulbar compartment syndrome. The canthal tendons create the anterior border to the orbital compartment; thus, cantholysis increases the size of the orbital compartment, equivalent to performing a fasciotomy elsewhere on the body. **Do not delay treatment with canthotomy and cantholysis by obtaining a CT scan for further proof of hemorrhage.** Vision loss due to compartment syndrome is generally severe and irreversible, while the periocular tissues are repairable and will readily heal if these procedures are performed prematurely.

LATERAL CANTHOTOMY AND CANTHOLYSIS: THE PROCEDURE

1. If possible, give subdermal injection of lidocaine 2% with epinephrine to the lateral canthus. It can be difficult to inject tissue that is already swollen.
2. Optional (only with good local anesthesia): Apply a hemostat or needle driver horizontally at the lateral canthus for 1 minute to reduce bleeding.
3. Perform lateral canthotomy: Use blunt scissors to incise the lateral canthus, **full thickness**, for 1–2 cm to the lateral bony orbital rim.

4. Perform inferior cantholysis:
    a. With toothed forceps, grasp the lower eyelid firmly at the edge of the incised canthus (at the orbital rim) and apply traction away from the eye.
    b. Keeping one scissor blade behind the lid (in the conjunctival fornix) and one blade over the skin, angle the scissors toward the corner of the mouth or nasal ala. Make a **full-thickness** cut across the lower lid for a length of 1–2 cm. This should fully disinsert the lid. You may be able to palpate or "strum" the inferior part (inferior crus) of the lateral canthal tendon as a "guitar string" before cutting.
    c. If successful, the eyelid should swing freely and come completely away from the globe. If the eyelid remains in its normal position, use scissor tips to feel for residual tethering bands, and continue cutting until the lid swings freely.
    d. There may not be a "gush of blood" even with successful release.
5. Recheck vision and intraocular pressure. If the intraocular pressure remains elevated with poor vision and a tense orbit, then perform superior cantholysis, separating the upper lid from the orbital margin. Also consider giving 500 mg IV acetazolamide. Acetazolamide works by interfering with the sodium pump in the ciliary body, reducing the osmolality of the aqueous humor. This changes the osmotic gradient and reduces aqueous volume, thereby reducing intraocular pressure, improving optic perfusion, and reducing the risk of optic nerve ischemia.

■ Figure 23-4 illustrates the method of performing a lateral canthotomy and cantholysis.

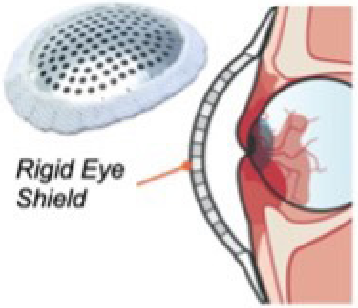
OPEN GLOBE

An open or ruptured globe should be suspected if examination of the eye shows an abnormally shaped eye, a peaked pupil, shallow AC, corneal or scleral laceration, pigmented tissue pushing through the sclera or cornea, or a foreign body in or protruding from the eye. A Seidel test can locate small leaks of aqueous fluid from the AC. To perform a Seidel test, anesthetize the eye, wet a fluorescein strip, and wipe the strip over the area of concern while keeping the patient from blinking. The undiluted fluorescein appears dark orange in normal light, but if a leak is present, it becomes light orange or green when viewed under blue light.

While ocular trauma scores help determine the degree and prognosis of globe injury (see online for a globe injury rating system), initial treatment of all open globes is the same. Once identified, immediately consult an ophthalmologist and describe the situation. Prepare the patient for surgery or transfer, because open globes are surgical emergencies that require immediate intervention. While awaiting patient transfer or specialist consultation, follow these steps to help protect the eye:

- Cover the affected eye with a rigid shield. If a foreign body is sticking out of the eye, cut a foam or paper cup to accommodate the foreign body. **Never place a pressure dressing, gauze, or other soft material under the rigid shield,** because the pressure may force contents out of the eye, and gauze or soft eye pads can stick to any extruding iris or other ocular contents, which might then be pulled out of the eye when removing the pad (**■ Figure 23-5**).

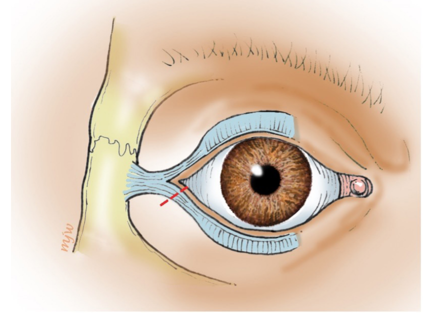
■ Figure 23-5: Application of Rigid Eye Shield to Protect an Open Globe. Clinicians should avoid using "patches" that might put pressure on an open globe, or using any adherent dressing that might exacerbate extrusion of globe contents when the dressing is removed. A rigid shield to protect they open globe is the best option.



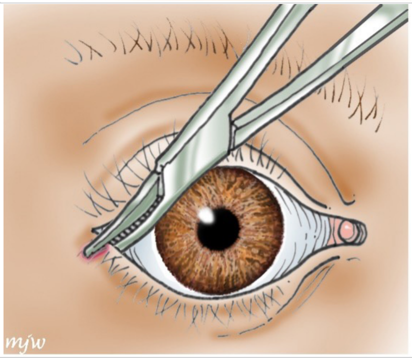
- Provide an IV antibiotic. **Fluoroquinolones are the only class of antibiotics that penetrate the vitreous at therapeutic concentrations when given by an IV or oral route.** Due to higher-vitreous penetration, ophthalmologists prefer newer fluoroquinolones like moxifloxacin, gatifloxacin, or levofloxacin—some advocate for the addition of vancomycin to the regimen for extended coverage. For patients with oral restrictions awaiting surgery, preferentially use IV formulations. If fluoroquinolones are unavailable, give IV broad-spectrum antibiotics to cover gram-negative and gram-positive bacteria.
- Ensure the patient is up to date with tetanus immunization.
- Explain to the patient the importance of minimizing eye movement if possible. Extraocular muscle movement can cause further extrusion of intraocular contents. The brain links eye movements, and moving the good eye also causes the injured eye to move.
- If the spine has been clinically cleared, elevate the head of the bed to 30 degrees. If the spine cannot be cleared, consider placing the patient in reverse Trendelenburg to approximate 30-degree elevation.
- Treat pain, nausea, and coughing aggressively. Valsalva maneuvers can increase pressure on the back of the eye (through the venous system), so reduce these activities to help keep intraocular contents inside the eye. If the patient is intubated or has an airway in place, request limited use of excessive positive pressure or coughing.
- **Minimize manipulation of the eye.** Do not perform any examination beyond visual acuity and observation.

■ **Figure 23-4: Lateral Canthotomy and Cantholysis.** Orbital compartment syndrome caused by orbital hemorrhage is an ocular emergency; vision can be affected in as little as 90 minutes. Lateral canthotomy and cantholysis can relieve pressure and possibly prevent loss of sight.

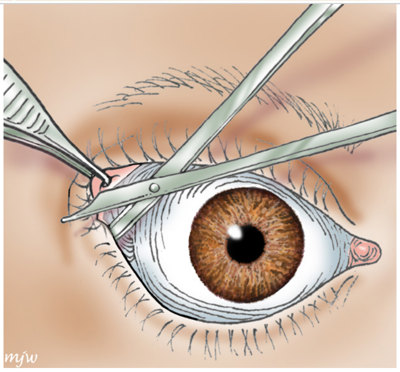
1. Identify the lateral canthus and if possible, anesthetize it with a subdermal injection of lidocaine 2% with epinephrine.



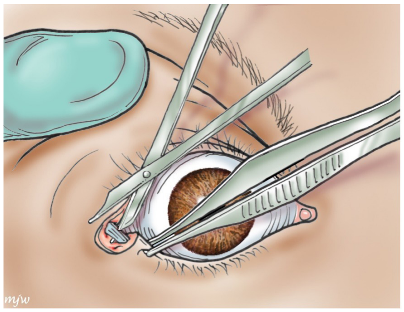
2. If the canthus was anesthetized, apply a hemostat or needle driver horizontally at the lateral canthus for 1 minute to reduce bleeding.



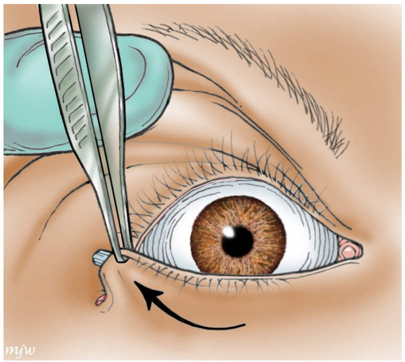
3. Perform lateral canthotomy: Use blunt scissors to incise the lateral canthus, full thickness, for 1–2 cm to the lateral bony orbital rim.



4. Perform inferior cantholysis: With toothed forceps, grasp the lower eyelid firmly at the edge of the incised canthus (at the orbital rim) and apply traction away from the eye. Keeping one scissor blade behind the lid (in the conjunctival fornix) and one blade over the skin, angle the scissors toward the corner of the mouth or nasal ala. Make a full-thickness cut across the lower lid for a length of 1–2 cm. This should fully disinsert the lid. You may be able to palpate or "strum" the inferior part (inferior crus) of the lateral canthal tendon as a "guitar string" before cutting.



5. If successful, the eyelid should swing freely and come completely away from the globe. If the eyelid remains in its normal position, use scissor tips to feel for residual tethering bands, and continue cutting until the lid swings freely. There may not be a "gush of blood" even with successful release.



Recheck vision and intraocular pressure. If the intraocular pressure remains elevated with poor vision and a tense orbit, then perform superior cantholysis, separating the upper lid from the orbital margin.

Also consider giving 500 mg IV acetazolamide. Acetazolamide works by interfering with the sodium pump in the ciliary body, reducing the osmolality of the aqueous humor. This changes the osmotic gradient and reduces aqueous volume, thereby reducing intraocular pressure, improving optic perfusion, and reducing the risk of optic nerve ischemia.

- Order a CT scan (only if planned treatment is in your facility) with fine cuts through the orbits to look for a foreign body or other ocular injuries. Each hospital has a slightly different orbital protocol, but generally, the cuts are 1 mm or less. IV contrast is not required. **Do not delay a transfer to get a CT scan.**

When you suspect an open globe, call an ophthalmologist for immediate examination to make a definitive diagnosis. These injuries require prompt treatment.

BLUNT TRAUMA: HYPHEMA

When examination of an otherwise intact eye (nonopen globe) shows a poor view behind the cornea (difficult to see the iris or pupil clearly), a hyphema (visible blood in the AC, between the cornea and the iris) is present. The eye sustained significant trauma and is also at high risk of elevated eye pressure. When blunt forces do not result in an open globe, they can still injure contents within the globe. Blood in the AC often comes from damage to the iris or its attachments to the scleral wall. Hyphema has two forms: (1) dispersed, with red blood cells floating in the aqueous humor and thus making the patient's vision and your view into the eye hazy; or (2) layered, with blood on top of the iris (or with blood inferiorly, if gravity has shifted the blood cells down). Patients will need to be on bed rest for multiple days. Place an eye shield and call an ophthalmologist to manage a hyphema.

ORBIT FRACTURE: SCREEN FOR ENTRAPMENT

If evaluation rules out a compartment syndrome but there is a restriction of eye movement—primarily if associated with significant pain, nausea, light-headedness, and diaphoresis—an orbit fracture with muscle entrapment should be suspected, especially if present in a young adult or child. Repair should occur within 48 hours of onset to avoid muscle ischemia and permanent damage. When entrapment exists, most commonly a floor fracture has hooked the inferior rectus muscle—screen for this by asking the patient to look up, and see if their eye moves appropriately (you can compare it to the unaffected eye). **If the patient has difficulty with this upward eye movement, or if the upward movement causes nausea or emesis, be very concerned about entrapment.** Consult an ophthalmic specialist to evaluate for this condition immediately.

EYELID LACERATION

Lid lacerations commonly occur due to dog bites, cat scratches, or other sharp objects near the eye. These lacerations are sometimes in conjunction with open globes; **excluding an open globe is the top priority.** Once open globe is excluded, look at the medial aspect of the lids to see if there is a tear near the punctum or through the canalicular duct. It is important to note if injury to the nasolacrimal system is present, as this often requires repair by oculoplastic subspecialists and is best repaired within the first 24–72 hours, before significant tissue swelling develops. Early recognition allows for the most effective repair (within 72 hours of injury) to prevent chronic tearing.

SPECIAL CONSIDERATIONS: OCULAR INJURIES IN CHILDREN

Be especially cautious of open globes in children. Examination often requires sedation, as crying with Valsalva maneuvers pushes additional ocular contents out of the eye. Choice of IV antibiotics in children is slightly controversial; many choose to offer fluoroquinolones, as the risk of endophthalmitis is higher than that of side effects from a short-term course, and fluoroquinolones allow for discharging on oral regimens after surgery. Discuss the situations and risk factors with the family, and document the discussion. An acceptable IV option of vancomycin plus an extended-spectrum cephalosporin offers coverage without side effects but limits discharge options following surgery.

TRANSFER

After managing and stabilizing ocular injuries covered within ATLS, ophthalmic specialists should provide definitive assessments and therapy. If your facility does not have ophthalmologists, transfer patients to tertiary centers that do. Timing is of the essence to save vision. Remember to do the following:

- Irrigate chemical injuries before even contacting an ophthalmologist (act immediately).
- Perform a lateral canthotomy and inferior cantholysis before transferring to an ophthalmologist (irreversible ischemia occurs within 90 minutes of injury).
- Shield the eye and start antibiotics before transferring open-globe injuries (surgical closure preferred ASAP, ideally within 12 hours but acceptable within 24 hours).

Patients with ocular injuries suffer from nausea, pain, and vision loss. Often, patients require medical support and guidance throughout the transfer and transport process.

PRACTICE ENVIRONMENT CONSIDERATIONS

Concerted efforts exist to increase the availability of ophthalmic coverage after hours and in rural settings. Unfortunately, standalone surgical centers, outpatient specialty clinics, and subspecialization contribute to the lessened presence of ophthalmic coverage in many emergency departments. Learning the basic ocular assessment and management skills in this chapter allows for care extensions that save patients' vision if they are far from immediate ophthalmic intervention.

CHAPTER SUMMARY

Timely assessment and intervention in ocular trauma cases are essential. Treatment teams must recognize the signs and symptoms of various ocular conditions, such as chemical injuries, orbital compartment syndrome, and open globe injuries. Once these three diagnoses have been ruled out or managed, consider evaluating and treating other injuries, such as eyelid lacerations or orbital fractures. Feel confident assessing and treating ocular injuries; when in doubt, prioritize initial stabilization measures and transfer to ophthalmology.

■ Figure 23-6: Ocular Trauma Flowsheet. The recognition of and prompt initialization of treatment for emergent ocular injuries, such as chemical injuries, ocular compartment syndrome, open globe injuries, and hyphema, can help prevent vision loss. The initial phases of treatment for these injuries may be accomplished by the emergency area clinician while awaiting a formal ophthalmologic consult.

OCULAR TRAUMA ASSESSMENT PRIORITIZED BY TIME

DIAGNOSES 1-2-3 CAN OCCUR INDEPENDENTLY OF EACH OTHER

1 CHEMICAL INJURY

The first thing we want to assess for is, Does the patient have a **chemical injury?**

Does the patient have evidence of a chemical (especially acid or alkali) injury (liquid splash or solid foreign body to the eyes or periocular area?

Chemical Injury requires immediate attention.

TREATMENT

Begin Chemical Injury Protocol: Treatment of Copious irrigation.

Chemical injury protocol-Copious irrigation (Morgan lens or IV tubing) of a >1 liter of normal saline or Lactated Ringers to the eyes until pH is neutral.

Call ophthalmology ASAP.

NEXT ASSESSMENT

2 COMPARTMENT SYNDROME

Does the patient have evidence of an orbital hemorrhage/compartment syndrome?

- Swollen, bruised, and firm-feeling eyelids
- Protruding eye, firm to palpation
- Significant blood under the conjunctiva
- Poor eye movement in most gazes
- Possibly poor vision and afferent pupil defect

Treatment needed within 60-90 minutes.

TREATMENT

Perform a canthotomy and cantholysis.

Cut the outer corner of the eyelids with scissors, straddle on either side of the angle where the upper and lower eyelid joins. Then angle the scissors within that incision about 45 degrees downward and toward the tip of the nose. Cut the tissue until the lower eyelid releases and the pressure is relieved.

Call ophthalmology ASAP.

NEXT ASSESSMENT

3 OPEN GLOBE

Misshapen eye, distorted pupil, foreign body in or protruding through the eye, pigment or intraocular contents coming out of an opening in the cornea or sclera, pigment under the conjunctiva.

TREATMENT

Put a rigid shield or cup over the eye without pressure on the eye.

Tape it so the edges rest only on the bony supported structures around the eye. Administer IV antibiotics, tetanus up to date.

Call ophthalmology ASAP.

NEXT ASSESSMENT

DIAGNOSES 4-5-6 CAN OCCUR SIMULTANEOUSLY

4 BLUNT TRAUMA TO THE GLOBE HYPHEMA

Is there a hyphema?
Globe intact but:
Blood between the cornea and iris, hazy view behind the cornea
Distorted pupil, elevated intraocular pressure

TREATMENT

Manage pain

Manage pain, nausea and vomiting.

Call ophthalmology ASAP.

5 ORBITAL FRACTURE(S)

Is there an orbit fracture with muscle entrapment?
No compartment syndrome
Restricted eye movement with double vision, significant pain with eye movement, nausea, light headedness, diaphoresis with eye movement

TREATMENT

Call ophthalmology ASAP.

6 EYELID LACERATIONS

Does the patient have evidence of an eyelid laceration, especially with possible canalicular involvement?

Abnormal lid position, obvious skin break or torn lid, especially involving the inner 1/3 of the eyelids closer to the nose.

TREATMENT

Keep eyelids moist with wet gauze or antibiotic eye ointment.

Consult ophthalmology.

IF 'NO' FOR ALL DIAGNOSES

COMPLETE DETAILED EYE SURVEY:

- More accurate visual acuity
- Pupil exam
- Eye motility
- IOP (Intraocular pressure)

KEY LEARNING POINTS

- **Ocular injuries have the potential to blind a patient.**
- **Vision-threatening injuries require treatment promptly after onset.**
- **Perform the ocular exam during the secondary survey, after stabilizing life- and limb-threatening injuries. Remember: Life, limb, eyesight.**
- **Alterations in the eye's three "vital signs" (vision, pressure, and pupils) can identify subtle ocular injuries that may threaten loss of sight if not immediately treated.**
- **Irrigate, irrigate, irrigate a chemical injury.**
- **Prompt canthotomy and cantholysis can save vision in cases of ocular compartment syndrome.**
- **Protect a potential ruptured globe with a shield, and prevent increased ocular pressure.**
- **When in doubt, consult immediately with an ophthalmologist.**

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24

Injury in Combat Zones and Austere Environments

OBJECTIVES After reading this chapter and acquiring the knowledge components of the ATLS® Course Manual, the learner will have the ability to do the following:

1. Describe challenges to providing injury care in combat zones and austere environments
2. Describe the differences in types of injuries encountered in combat zones compared to the civilian setting
3. List the modifications to the ATLS algorithm necessary in combat zones

24

Injury in Combat Zones and Austere Environments

CHAPTER STATEMENT

Care of the trauma patient during conflict requires additional considerations regarding environment, injury mechanisms, systems of care, and unique practice considerations. ATLS® for the Operational Environment (ATLS®-OE) provides a construct for understanding these key considerations.

INTRODUCTION

Trauma care capability and best practices in areas of conflict, natural disasters, or other austere settings may be highly variable, or potentially only available from external resources delivered to the battlespace or site of disaster. The many challenges of operating in this type of environment will impact every echelon of care, from the point of injury all the way through the evacuation to definitive care facilities. It is critical that all healthcare clinicians in these environments have an understanding of these limitations and how they will affect trauma care, as well as optimal strategies that can mitigate or even negate these disadvantages. Although Advanced Trauma Life Support® (ATLS®) has formed the critical foundation of care for the injured patient in both modern civilian and military environments, the experiences during the prolonged conflicts in Iraq and Afghanistan, as well as lessons learned from the recent Russo-Ukraine war, have dictated military-specific considerations and additions to standard ATLS principles and practice.

PRACTICE ENVIRONMENT CONSIDERATIONS

The operational or austere environment presents a wide variation in threats, injuries, human resources, and medical material availability that all must be taken into account when planning and executing healthcare operations during times of war. While ATLS provides the critical foundation of care for the injured patient in both civilian and military environments, additional considerations are necessary due to the multiple unique and challenging aspects of providing trauma care in a severely resource-limited environment.

Additional factors include operating in an environment with the continuous threat of hostile action, limited basic equipment and personnel capabilities, limitations in the supply and resupply chains, lack of the full range of modern diagnostic and therapeutic technology (such as CT scanners, MRI, angiography, etc.), and a significantly degraded or even nonexistent local healthcare infrastructure.

Additionally, many of these challenges may also be applicable to civilian trauma care in the remote rural environment, although typically to a lesser degree (■ **Table 24-1**).

SECURITY, COMMUNICATION, AND INFRASTRUCTURE

The tactical situation in any constrained environment is highly dynamic, resulting in varying degrees of threat. Both internal and external security concerns must be considered for the protection of both staff and patients. Measures may need to include increased physical plant security with **armed personnel or police presence** depending on the environment and situation; additional restrictions in facility access; screening and identity verification of staff, patients, and visitors; and the searching of vehicles and personnel for weapons. Depending upon the environment, **key infrastructure considerations, such as electrical power, lighting, and communications**, may also dramatically influence a facility's security posture. While these security needs will be most apparent in times of armed conflict, care must be taken to ensure that every treatment facility's operational plans fully address other scenarios, such as when a local facility is overwhelmed or incapacitated by natural disaster, riot, or intentional mass casualty event.

Likewise, reliable internal and external communication remains a vexing problem. Lack of system interoperability and reliance on native infrastructure such as vulnerable telephone landlines, computer networks, or cell phone systems are frequent communication limitations. Unfortunately, **failed or disrupted communications remain a frequent issue in military, disaster, and rural environments, and contingency plans must be established in advance.**

During times of war, movement of casualties from point of injury to initial care and between medical facilities may be hindered by the security environment or other constraints such as distance, weather, or lack of available assets. This may lead to prolonged periods of care at various locations throughout the continuum and may be overwhelming to smaller facilities at times. Additionally, there is often attrition of medical forces, loss of medical infrastructure, and destruction of medical resources due to either intentional targeting or proximity to other battlefield targets.

SPECIAL POPULATIONS

Special populations during times of conflict include civilians within the area of conflict who may be injured or displaced. Children are particularly at risk for injury and illness. Injuries to these populations may be both physical and psychological. Additionally, sexual- and gender-based violence is often more prevalent during times of conflict. Further complicating this situation is the disruption of societal infrastructure and potential loss of healthcare facilities.

■ **Table 24-1: Comparison of Factors Impacting Trauma Care.**

Comparison of Factors Impacting Trauma Care in the Civilian Urban, Civilian Rural, and Operational/Disaster Environments

	Civilian Urban	Civilian Rural	Operational/Disaster
Threat level	None	None	High
Resources	Readily available	May be limited	Severely limited
Personnel	Excess	Limited but expandable	Fixed and limited
Supplies/ Equipment	Fully equipped, resupply readily available	Adequately equipped, delay to resupply	Limited supplies, resupply significantly delayed
Available Expertise	Full subspecialty services	Limited specialties locally available	No subspecialty services immediately available
Transfer Availability	Immediately available	Available but longer transport times	Highly variable, may be no option for transfer
Multiple or Mass Casualty Events	Uncommon	Rare	Common

SPECIFIC INJURY MECHANISMS

WAR WOUNDS

It is important to consider the unique wounding patterns associated with weapons of war, such as injuries resulting from high-velocity firearms and high-energy explosives. High-energy gunshot wounds, such as those from assault rifles, are created by the linear and cavitating (radial) energy of the missile and cause tissue devitalization and destruction outside the actual path of the missile. High-energy explosives are commonly found in military munitions or in the commercial-grade explosives often seen in improvised explosive devices (IEDs). Explosions from these weapons cause multidimensional blast injuries across four mechanisms: primary blast from the supersonic pressure wave; secondary blast from fragments; tertiary blast from blunt or penetrating impact in the environment; and quaternary blast from burns, crush injuries, or infections. While IEDs are most often encountered in theaters of war, they are also increasingly utilized as a weapon of choice for intentional mass casualty events at home and abroad. Mortality and morbidity depend upon the distance from the device, extent of available protection, and proximity to immediate medical support. A prominent injury pattern during the Iraq and Afghanistan conflicts, known as **dismounted complex blast injury,** includes multiple traumatic amputations, pelvic injury, and traumatic brain injury (■ **Table 24-2**).

■ **Table 24-2: Common Blast Injury Patterns Seen on the Battlefield.**

Common Blast Injury Patterns Seen on the Battlefield

Blast mechanism	Common injuries	Primary Cause of Mortality
Mounted	Closed extremity fractures, spine fractures, traumatic brain injury	Traumatic brain injury
Dismounted, low energy	Open and closed extremity fractures, amputations, multiple open wounds, vascular injury	Hemorrhage
Dismounted, high energy	Multiple traumatic amputations, open and closed pelvic fractures, spine fractures, traumatic brain injury, crush injury	Traumatic brain injury, hemorrhage, delayed complications of wounds or multiorgan failure

Low-energy explosives, such as gunpowder in pipe bombs or pressure cookers, tend to produce mostly secondary blast injuries from fragments in a smaller radius; however, those close to such explosions may have primary blast injury, extensive penetrations, and amputations.

Initial management includes immediate hemorrhage control and resuscitation, followed by early wound irrigation of contamination and debridement of devitalized tissue. One must maintain a hypervigilant index of suspicion for internal damage, including vascular injuries, because high-energy blasts often result in a complex combination of wounds, ranging from devastating traumatic amputation to multiple small penetrating wounds with highly variable penetration and wound trajectories that are extremely difficult to assess without adjunct imaging.

RADIATION AND CHEMICAL AGENTS

Radiological and chemical agents may also be involved in conflict, industrial accidents, terrorist attacks, or as a consequence of natural disasters, such as at Fukushima. Deployed medical units must provide means to detect these agents and decontaminate patients as needed prior to assessing and performing initial management of associated injuries. The US Department of Health and Human Services Administration for Strategic Preparedness and Response's Radiation Emergency Medical Management (REMM) and Chemical Hazards Emergency Medical Management (CHEMM) websites and apps are good planning resources for radiation and chemical exposure management. Further complicating matters is the fact that when these agents are used in warfare, the injury pattern often includes not only the insult from the radiation or toxin but also other aspects of polytrauma and burn injury. Depending upon the toxin and degree of exposure, this may impact the anticipated prognosis and treatment options.

SYSTEM CONSIDERATIONS

JOINT TRAUMA SYSTEM AND TACTICAL COMBAT CASUALTY CARE

Mortality from combat wounds steadily improved over the course of the wars in Iraq and Afghanistan despite an increase in Injury Severity Scores. This trend stems from improvements in protective equipment, establishment of a system of in-theater trauma care, use of tourniquets, application of damage control surgery and resuscitation, and use of long-range critical care transport for the most severely injured. This was only possible due to the widespread implementation of Tactical Combat Casualty Care (TCCC) and the establishment of the US Department of Defense's Joint Trauma System (JTS), which supports trauma readiness and outcomes through evidence-driven performance improvement. Today, through maintenance of the Department of Defense Trauma Registry, JTS Clinical Practice Guidelines, and TCCC guidelines, the JTS ensures high-quality trauma care throughout the US military's globally deployed trauma system. Additional resources including guidelines for deployed trauma care can be found on the JTS website (https://jts.health.mil/).

A precedent for the modification of civilian trauma training courses to incorporate military-specific needs can be found in the example of Prehospital Trauma Life Support (PHTLS) and TCCC. Initially developed as a curriculum for US Special Operations Command, TCCC has now been implemented across the battlefield and is the standard for combat prehospital care. A Military Edition of the PHTLS textbook was developed to help support this curriculum. The widespread implementation and training of all combat personnel in TCCC as competent initial responders has resulted in demonstrable reductions in preventable death on the battlefield.

TCCC divides point of injury care into three distinct phases:

1. Care Under Fire
2. Tactical Field Care
3. Tactical Evacuation

CARE UNDER FIRE

Care Under Fire is the care rendered by fellow soldiers ("buddy aid") or the unit medic or corpsman at the scene of the injury while both the immediate responder and the casualty are still under effective direct or indirect hostile fire. The primary focus for this phase of field medical care is fire superiority and suppression of the source of ongoing attacks. The only medical intervention conducted in this phase is rapid control of ongoing hemorrhage, typically by application of a tourniquet and/or hemostatic dressing, which can be self-administered or applied by a fellow combatant or a combat medic.

TACTICAL FIELD CARE

Tactical Field Care is provided by the medic or corpsman once no longer under effective hostile fire. This phase of care can be highly variable dependent upon the setting, but all efforts should be expended to minimize the time from injury to arrival at a forward medical treatment facility with surgical capabilities. In addition, reengagement with the enemy remains a possibility and must always be anticipated. In this phase of care, the standard critical prehospital trauma assessments and interventions are conducted. The new xABCDE approach emphasized in ATLS 11th Edition is in alignment with TCCC, which emphasizes hemorrhage control (or "x") first, followed by airway and breathing. The most common cause of potentially preventable deaths on the modern battlefield (up to 90%) is uncontrolled hemorrhage. In this phase of care, any additional bleeding is controlled with tourniquets or pressure dressings, and resuscitation with available blood products and tranexamic acid is started. Other interventions that are highlighted in this phase include establishing or maintaining an airway, decompression of tension pneumothorax, pain control, antibiotic administration, and preparation for transport to the next echelon of care.

TACTICAL EVACUATION CARE

Tactical Evacuation Care is care rendered once the casualty has been placed in the medical evacuation (MEDEVAC) platform and includes care provided from the point of injury and during transport to the most appropriate higher-level medical facility. Care in this phase focuses on continuation of the initial interventions performed in the Tactical Field Care phase, assessment and intervention for any additional life- or limb-threatening injuries, and initiation of fluid resuscitation, pain control, and antibiotic therapy (if not already begun). More detailed evaluation and greater options for intervention are indicated in this phase of care, with the caveat that the primary philosophy involves minimizing unnecessary or nonurgent interventions and focusing on rapid transportation to a higher level of care.

SPECIFIC ADJUNCTS AND TREATMENTS

TOURNIQUETS

The immediate arrest of exsanguinating extremity hemorrhage with a tourniquet is the principal life-saving intervention delivered in the Care Under Fire stage and is considered the standard of care for the prehospital environment. Because it is frequently difficult to ascertain the exact location of bleeding on an extremity during Care Under Fire, TCCC recommends the immediate placement of a "high and tight" tourniquet at the shoulder or groin. During later phases of Tactical Field Care or on arrival to the next echelon of care, these hastily placed tourniquets must be assessed for replacement in a location 2–3 inches above the wound, conversion to a pressure dressing, or removal if not necessary.

■ Box 24-1: Tourniquet Pitfall and Mitigation.

Tourniquet Pitfall and Mitigation

Pitfall	Mitigation
Leaving a "high and tight" tourniquet in place for bleeding wound	Tourniquet replacement (2-3" above wound) or conversion at earliest opportunity. Consider during ATLS secondary survey if tourniquet still in place.
Converting a tourniquet during profound shock	Administer blood and reassess. Consider tourniquet replacement or conversion as soon as possible once clinically improved.
"High and tight" tourniquet placed for traumatic amputation	Perform tourniquet replacement once shock is improved.

While the widespread adoption of tourniquets in both military and civilian settings over the last two decades has been an integral component of improving prehospital mortality, studies in both settings have also revealed that up to half of the tourniquets that are placed emergently are not necessary for hemorrhage control in hindsight. This further reinforces the importance of tourniquet replacement or conversion at the earliest opportunity. In recent US military conflicts, as well as most civilian prehospital settings, rapid evacuation to an initial facility for damage control surgery allowed tourniquet replacement or conversion to occur at the treatment facility.

However, experiences in the Ukraine conflict have highlighted the importance of early tourniquet replacement or conversion within 2 hours of injury to prevent unnecessary limb loss. In cases of prolonged tourniquet use, tourniquet conversion or replacement may be accompanied by a systemic post-tourniquet syndrome that includes hypotension, acidosis, and acute renal failure. While tourniquet replacement may occur, tourniquet conversion should not be attempted in patients with profound shock until resuscitation has been started. Additionally, tourniquets should never be converted to a pressure dressing in cases of traumatic amputation until evaluated by a surgeon.

FAR FORWARD BLOOD

In addition to external hemorrhage control, optimal survival in the prehospital setting relies on the availability of adequate resuscitation resources. Several military and civilian studies have now suggested a likely mortality benefit for early prehospital blood in the bleeding patient. In order to provide blood as near to the point of injury as feasible, the US military now maintains FDA-compliant, low-titer (anti-A/anti-B <256), type-O cold-stored whole blood, as well as other components (such as dried plasma) for use in the field.

Additionally, when stored blood products are unavailable, the US military utilizes emergency blood collection (also known as "walking blood bank") to provide fresh whole blood to injured casualties in extremis. Potential donors are screened prior to deployment for blood type, transfusion-transmitted infections, and titer so that low-titer, type-O donors are preidentified and immediately available in the field setting when needed.

These emergency procedures enable forces in the field to provide life-saving blood transfusions when standard blood products are unavailable or have been depleted, thereby facilitating movement of the casualty to a damage control surgery capability. Additional information on the procedures and training used for emergency fresh whole-blood collection can be found in the Joint Trauma System Whole Blood Clinical Practice Guideline or the resources listed at the end of the chapter.

ATLS IN THE OPERATIONAL ENVIRONMENT (ATLS-OE)

Just as TCCC provides an operational companion to the standard civilian PHTLS course, there was an identified need to create an equivalent product for the standard ATLS Course. ATLS-OE is a course of instruction that emphasizes the importance of maintaining situational awareness while providing care in a potentially hostile, resource-constrained, and manpower-limited environment. The unique situational and environmental factors in the operational setting often include severely constrained resources or supply chains, variable communication capabilities, limited evacuation and transport options, extremes of weather, and a dynamically changing security or tactical environment. In addition, the numbers of casualties, severity and types of injuries, and wounding mechanisms seen with modern combat or even large-scale disasters may be considerably different from standard civilian trauma patterns.

The various unique challenges of the operational or combat environment require clinicians to be ever cognizant of these challenges, which rarely present an issue in the stable civilian environment—although some of these same concepts are also applicable to the remote rural environment. Clinicians faced with rendering trauma care in an austere environment will be required not only to deliver high-quality modern trauma care but to do so without the benefit of many of the things that are routinely available in civilian settings; ATLS-OE emphasizes the unique challenges described above and seeks to provide learner with the additional information that will be paramount to success in these difficult environments. ATLS-OE provides this additional subject matter through the supplementation of the standard ATLS curriculum with additional military relevant information.

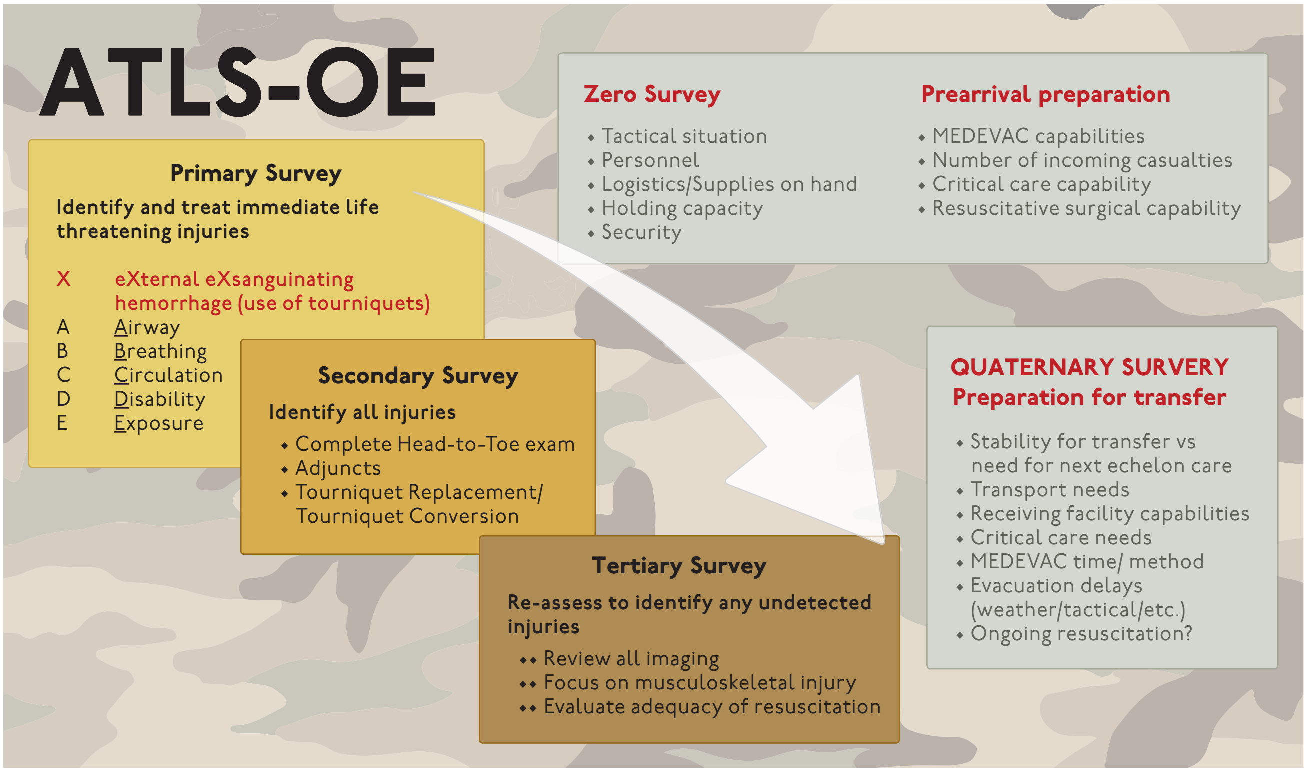
Additionally, while the standard course teaches the primary, secondary, and tertiary surveys, a key foundation of ATLS-OE involves the addition of two additional surveys that must be incorporated into the trauma survey: the *Zero* and *Quaternary Surveys*. These surveys are necessary as initial trauma care in the austere environment requires careful consideration of internal capabilities and external factors (Zero Survey) and patients are often rapidly transported across multiple facilities and require careful attention be paid to preparation for safe evacuation to the next higher echelon of care (Quaternary Survey) (■ **Figure 24-1**).

ZERO SURVEY

The standard ATLS Course briefly addresses preparation to receive trauma patients as they flow from the prehospital environment to the hospital. The Zero Survey is implied, but it is not specifically characterized or formalized as a separate named survey. ATLS-OE formalizes this prearrival preparation as a critical concept for the learner. While this preparation is important to the care of any severely wounded patient, it is absolutely critical as the first step in making appropriate triage decisions in the setting of multiple casualties.

The process emphasizes the importance of an accurate inventory of local resources, staffing, expertise, environmental and operational conditions, and any other anticipated or potential challenges in preparation for the arrival of one or more injured patients. The Zero Survey will identify clinician or systems issues that may not yet have been identified or mitigated and that may have a significant impact on decisions made during the initial evaluation. These are factors and issues that the learner may have never considered but that may be of equal or even greater importance than the actual patient injuries or required interventions. The Zero Survey will dictate how patients are triaged and prioritized, what injury types or patterns exceed the local capabilities or available expertise, and which resources are in short supply or not available.

■ **Figure 24-1: Expanded ATLS-OE Trauma Survey.** This survey incorporates tourniquet use into Primary survey and includes Zero and Quarternary surveys. OE, Operational environment.


ATLS-OE
Zero Survey
• Tactical situation
• Personnel
• Logistics/Supplies on hand
• Holding capacity
• Security
Prearrival preparation
• MEDEVAC capabilities
• Number of incoming casualties
• Critical care capability
• Resuscitative surgical capability
Primary Survey
Identify and treat immediate life threatening injuries
X eXternal eXsanguinating hemorrhage (use of tourniquets)
A Airway
B Breathing
C Circulation
D Disability
E Exposure
Secondary Survey
Identify all injuries
• Complete Head-to-Toe exam
• Adjuncts
• Tourniquet Replacement/ Tourniquet Conversion
Tertiary Survey
Re-assess to identify any undetected injuries
• Review all imaging
• Focus on musculoskeletal injury
• Evaluate adequacy of resuscitation
QUATERNARY SURVERY
Preparation for transfer
• Stability for transfer vs need for next echelon care
• Transport needs
• Receiving facility capabilities
• Critical care needs
• MEDEVAC time/ method
• Evacuation delays (weather/tactical/etc.)
• Ongoing resuscitation?

These factors will include the following:

- How many and what type of medical personnel are available?
- What medical and surgical expertise or specialties are available?
- What amount and type of blood products are available?
- What are the critical supply shortages, if any?
- Is resupply available on short notice, including blood products?
- Is there a need to initiate a fresh whole-blood drive?
- What is the available source of oxygen, and how much supply is currently available?
- Is direct communication with the next echelon of care available if a transfer is required?
- What is the tactical situation, and is security adequate?

It is the fluidity and potential chaos inherent to the austere environment that dictate the importance of the Zero Survey in practice. Triage decisions and initial care priorities may change rapidly as the situational factors and care capacity of the facility evolve over time and between events. In this environment, as personnel and supply resources become more limited, triage decisions become increasingly difficult.

QUATERNARY SURVEY

Although the standard ATLS Course emphasizes preparation of the injured patient for transfer from the initial facility to a trauma center, this is typically a single transfer over a relatively short distance by a fully equipped medical team. In contrast, a patient in the operational environment may undergo multiple sequential transfers over prolonged distances, while initial resuscitation is ongoing. It is not uncommon to have a patient undergo a major damage control surgery and then be placed into the medical evacuation continuum within minutes to hours of surgery and/or injury. These transfers may be via helicopter, ground ambulance, or even watercraft, making ongoing, enroute care exceedingly challenging. Therefore, strict attention must be paid to the complete preparation of the patient for safe transportation in order to minimize the likelihood of problems or complications arising during transport.

The Quaternary Survey formalizes this preparation for transfer. It should be repeated for each successive transfer in the medical evacuation chain. In the operational setting, the time in transit may be a matter of minutes or may be many hours, and this must also be factored into not only the preparation for transport but also the decision about readiness for transport. Enroute care capabilities must also be considered, because they may vary widely in terms of the transportation platform, available enroute care providers, equipment, supplies and medications, environment, and the potential for external threats.

Assessing the patient's response to resuscitation is critical. The potential of meeting desirable end points of resuscitation versus the local resources to meet these end points are real and important considerations. Although it is certainly desirable to ensure that a severely injured patient is clinically stable, has had a complete and thorough evaluation with identification of all injuries, and has been fully resuscitated to standard end points, this is often not practical or possible in the operational environment. The limited supply of critical resources such as blood products, as well as the limited holding capacity of the most forward medical treatment facilities (such as the Forward Surgical Team), make prolonged care and sustained massive transfusions logistically impossible. Thus, often the best of two suboptimal choices must be made, and the patient is placed into the transport system at a much earlier phase or in a more tenuous point of their resuscitation than is frequently done in the civilian setting.

Additional considerations as patients are moved in the operational environment include the following:

- Will weather or hostile action prevent movement of casualties?
- What supportive treatments must accompany the patient (ventilator, suction), and what are the potential enroute problems or malfunctions that could occur?
- Will the evacuation team have the skills to manage a critically ill patient and the supportive equipment accompanying the patient?
- What medications, fluids, blood products, and other resuscitative or supportive treatments can realistically and reliably be administered during the transport?
- What protective equipment is needed to prevent hypothermia, eye injury, and ear/hearing injury during transport?

IMPLEMENTATION OF ATLS-OE

ATLS-OE is currently available for use at military ATLS sites and may be combined with additional skills curriculum for the maintenance of military trauma skills requirements. For more information on the ATLS-OE supplemental curriculum, contact the Region 13 (military) ATLS Chief.

IMPROVING SURVIVAL FROM ACTIVE SHOOTER AND INTENTIONAL MASS CASUALTY EVENTS: THE HARTFORD CONSENSUS AND STOP THE BLEED® CAMPAIGN

From 2000 to 2013, there were 160 active shooter events with 1,043 casualties and 486 deaths. Similarly, during the period from 1983 to 2002, there were over 36,000 explosive incidents with 6,000 injuries and nearly 700 deaths. The number of active shooter incidents increased by 60% since 2019. The extreme lethality of these events cannot be ignored.

With this in mind, in the aftermath of the tragic shootings at Sandy Hook Elementary School in 2012 and the Boston Marathon bombing in 2013, the Joint Committee to Develop a National Policy to Increase Survival from Active Shooter and Intentional Mass Casualty Events was established by the American College of Surgeons, in collaboration with leaders from various federal institutions including the National Security Council; US military and federal law enforcement agencies; police, fire, and emergency medical organizations; and several key healthcare organizations. The committee's efforts have been a national call to action to address survivability of these events and to train first responders and the lay public in the control of hemorrhage.

Given the high volatility of an active shooter event, the most important initial step is threat suppression by law enforcement personnel. However, the immediate priorities of rapid extremity hemorrhage control by trained first responders and expeditious transport of those with potentially noncompressible internal hemorrhage must be mitigated.

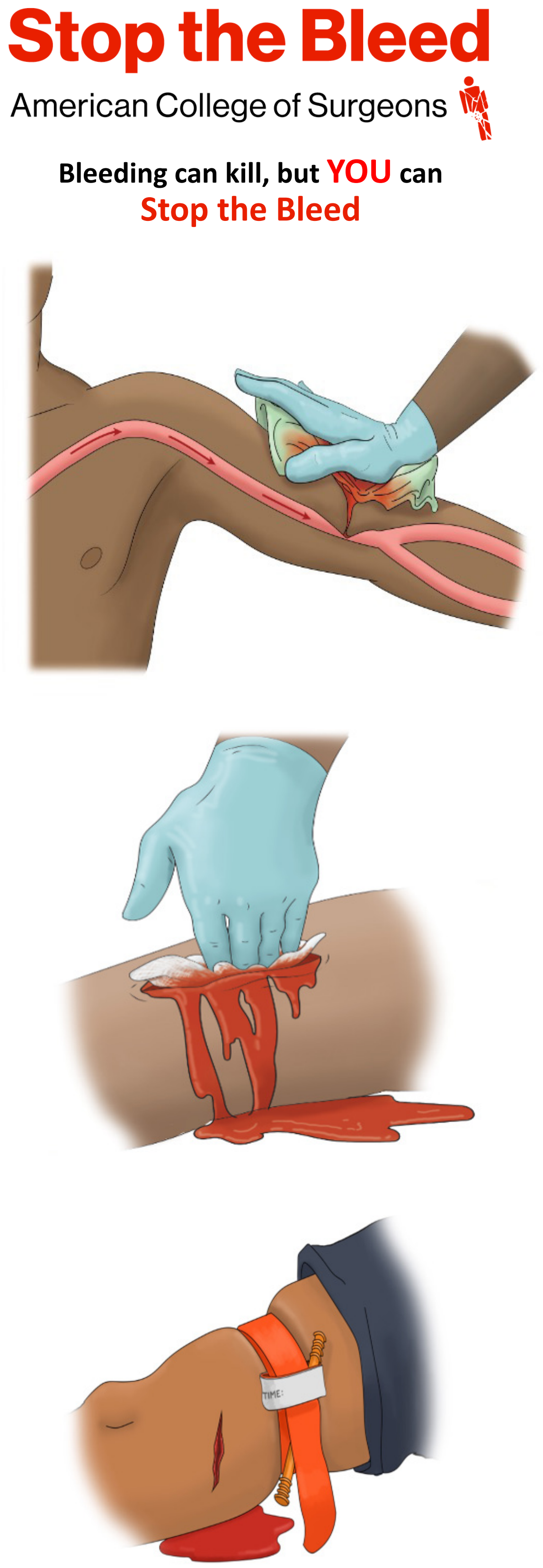
■ Box 24-2: The THREAT Acronym.

Critical Events in an Integrated Response to an Active Shooter Event are Represented by the Acronym: **THREAT**	
T	**T**hreat suppression
H	**H**emorrhage control
R	**R**apid
E	**E**xtrication
A	**A**ssessment by medical clinicians
T	**T**ransport to definitive care

Using lessons learned from the military's experience with TCCC, early external hemorrhage control must be the responsibility of the earliest person on scene, and law enforcement personnel should be trained and equipped to control bleeding with tourniquets and hemostatic agents. Similarly, emergency medical services (EMS) and fire personnel must shift operational tactics and develop new paradigms of emergency management coordination to push forward in support of rapid casualty evacuation.

The lay public should be trained in immediate bleeding control in a public health mandate similar to cardiopulmonary resuscitation (CPR) or the Heimlich maneuver. Appropriate bleeding control equipment (gloves, tourniquets, hemostatic dressings) should be readily available to all emergency personnel and in publicly accessible "hemorrhage control kits," which should be positioned in appropriate public venues and be as readily accessible and identifiable as automatic external defibrillators. Lastly, training alone is not enough; the lay bystander must be empowered to act in time of emergency (**■ Figure 24-2**).

■ Figure 24-2: Stop the Bleed Campaign. The Stop the Bleed® campaign empowers the lay responder to act.



CHAPTER SUMMARY

ATLS provides a framework of care that can be followed in combat and austere environments. Resources and environment play a critical role in the care that can be provided and timing of patient movement. Patients may require evacuation without having reached the ideal end points of resuscitation. Tourniquets should be reassessed ideally within 2 hours of placement.

KEY LEARNING POINTS

- **The principles of ATLS provide a framework for evaluating and treating life-threatening injuries in all situations and environments; however, these principles must be adapted to the situation based on available resources.**
- **Early hemorrhage control with tourniquets is critical; however, tourniquets should be reassessed for replacement or conversion at the earliest opportunity.**
- **ATLS-OE provides an expanded construct for assessment and resuscitation of the trauma patient in the military setting.**
- **Austere and operational environments require increased situational awareness and detailed prearrival and pretransfer assessments due to resource constraints.**
- **The Stop the Bleed campaign provides hemorrhage control training for the public and empowers immediate bystanders to act.**

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